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ABSTRACT

This manual on fasteners (devices used in home and shop to hold things together) is one of a series of power mechanics texts and visual aids on operation, diagnosis, and repair. Materials provide basic information and illustrations for use by vocational students and teachers as well as shop servicemen and laymen. Seven chapters are included: (1) Importance of Fasteners; (2) Bolts, Cap Screws, Nuts, and Locking Devices; (3) Working with Bolts, Cap Screws, and Nuts; (4) Screws, Keys, Studs, Pins, Snap Rings, Rivets, and Clamps; (5) Specialty and Plastic Fasteners; (6) Adhesives and Sealants; and (7) Tables, Torques, and Metrics. Each part concludes with test questions. Answers to the test questions are appended. (A supplementary 35mm color slide set is also availabile--see availability note.) (LRA)

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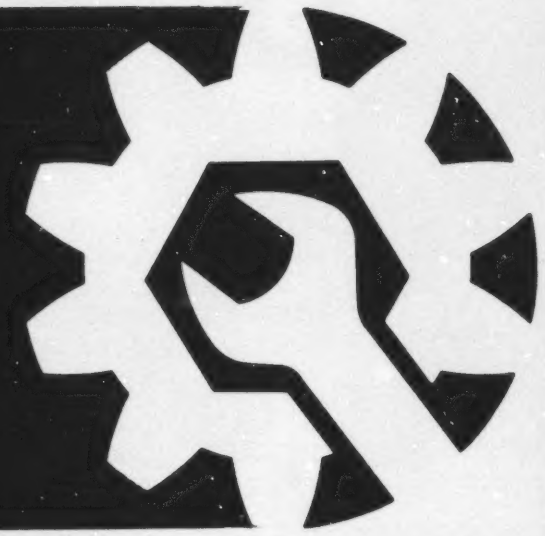
Fasteners

JOHN DEERE

FOS

FUNDAMENTALS OF SERVICE



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TO THE READER

PURPOSE OF THIS MANUAL

This manual is about fasteners. What is meant by "fasteners"? — Simple devices that are used every day in the home or shop to fasten things together — bolts, screws, nuts, pins, washers, keys, studs, snap rings, rivets, adhesives, and others.

A lot has been written about fasteners, but it is scattered in many publications, and is often written in technical engineering terms. One purpose of this manual is to consolidate in one publication, basic information on fasteners, written simply so it will be easily understood.

We've attempted to limit the information to those features of fasteners that will be of most interest and use to the reader — a description of each fastener; its purpose; its special uses; how it is designated and measured.

Included also are instructions for removing and installing certain fasteners if special techniques are necessary.

The meaning of special fastener terms and symbols, often technical and not always understood, are explained.

Because the proper tightening of many bolts, nuts, and cap screws has become very critical in modern high-powered, high-pressure, hard-working machines, a chapter discussing tension and torque is included.

If you work frequently with fasteners, you may be familiar with much of the information in this manual. Even so, by reading it, you may learn something new, and find some items of interest.

It is hoped that others not so experienced — shop trainees, vocational students, and interested laymen — may increase their knowledge by reading this manual; it is written in a simple form with many illustrations so it will be easily understood.

WHAT IS "FUNDAMENTALS OF SERVICE"

This manual is one of a series of texts and visuals called "Fundamentals of Service," or "FOS." These materials are basic information on power mechanics for use by teachers as well as shop servicemen and laymen. All types of modern equipment are covered — both automotive and off-the-road (construction and agricultural types). Emphasis is on theory of operation, diagnosis of trouble problems, and repair.

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FOR MORE INFORMATION

Write for a free FOS Catalog of Manuals and Visuals. Send your request to:

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This manual was prepared by Robert L. Marchant, Senior Technical Editor for John Deere Service Publications.

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Managing Editor: L.R. Hathaway
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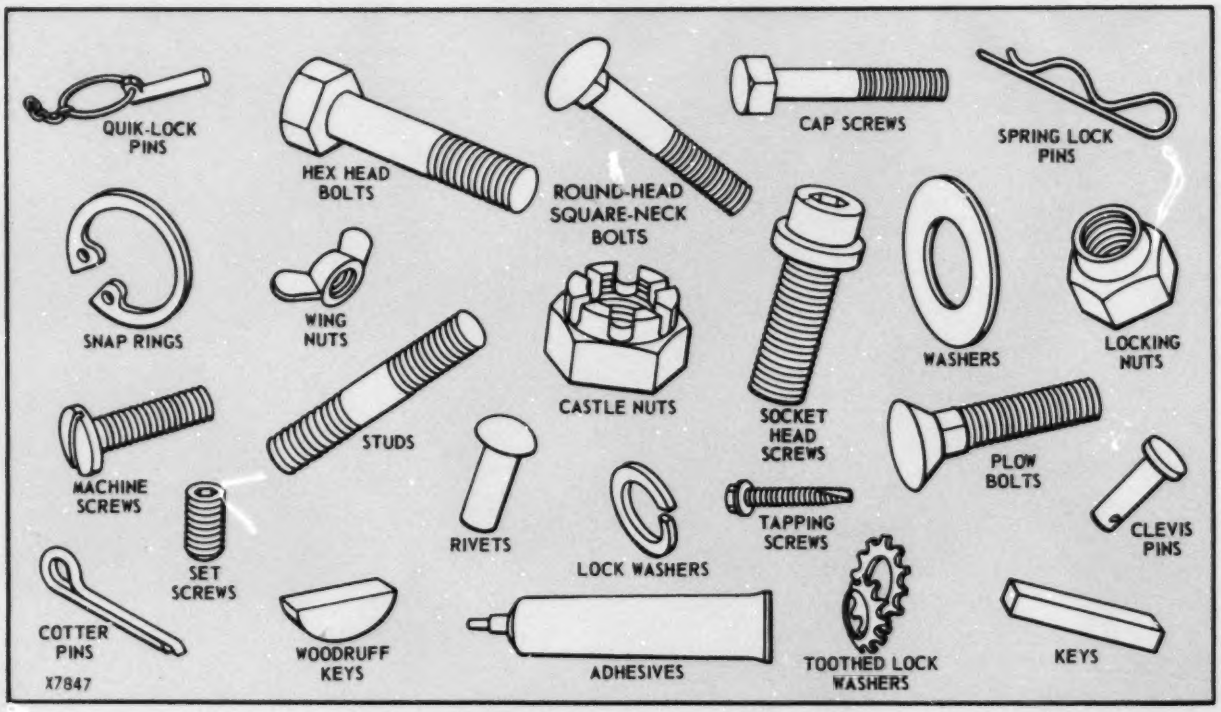

Fig. 1 — Typical Fasteners Discussed in This Manual

INTRODUCTION

Almost since the dawn of civilization, man has used fasteners to hold together the things he makes. Probably first came rope-like vines or reeds, leather thongs (Fig. 2) and simple wooden pegs. Gradually, as the need arose, he developed other more sophisticated fasteners until now there is a host of them — some simple like buttons, safety pins, zippers, paper clips, nails (Fig. 3); others more complicated or developed for a special need such as high-strength bolts, lock nuts, keys.

Today few products could be made without fasteners. They are an important part of our everyday living and are encountered in almost everything we make or repair.

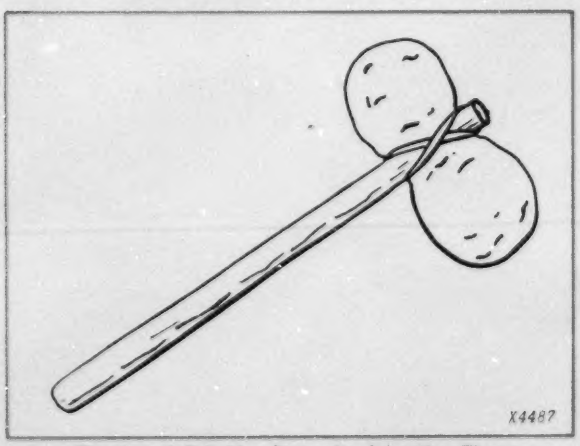

Fig. 2 — A Primitive Stone Ax. A Leather Thong Fastens the Head to the Handle.

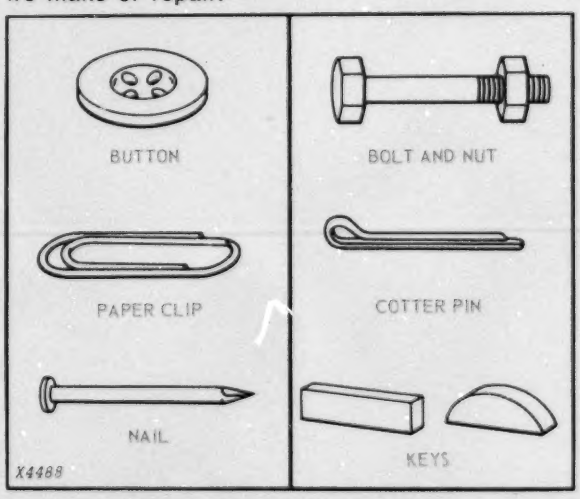

Fig. 3 — Common Modern Fasteners

WHY FASTENERS?

Fasteners are used today in manufactured products for a number of very important reasons:

They simplify manufacture. Because of their complexity, many components and assemblies cannot be made in one piece; they must be made of two or more parts (Fig. 4), held together by fasteners. Thus fasteners greatly simplify manufacture.

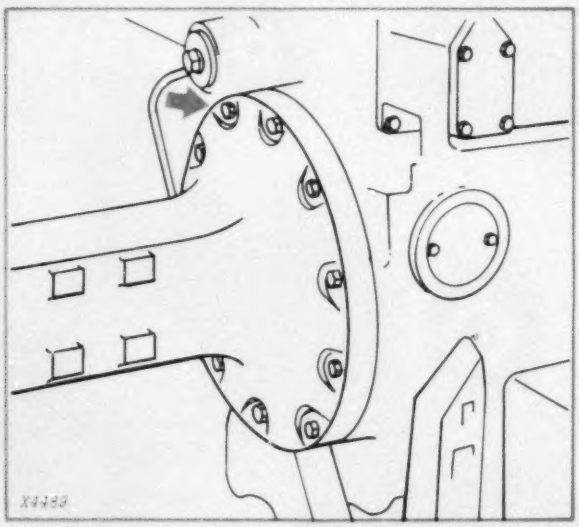

Fig. 4 — Tractor Rear Axle Housing Fastened to Differential Housing with Cap Screws

They simplify repairs. Fasteners also simplify the jobs of maintenance and repair; by removing the fasteners (Fig. 5), an assembly can be separated into the individual parts for inspection, repair or replacement.

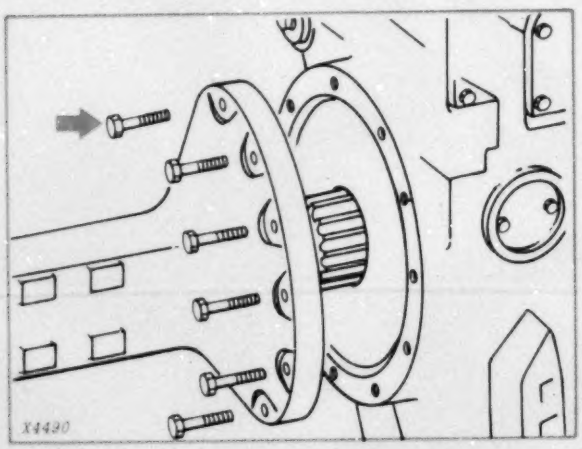

Fig. 5 — When Fasteners are Removed, the Assemblies Can Be Separated into Individual Components

They provide safety. Many fasteners also serve as safety devices. Such items as lock washers, cotter pins, lock wire, jam nuts assure that an assembly, once put together, will stay that way with little possibility of its coming apart.

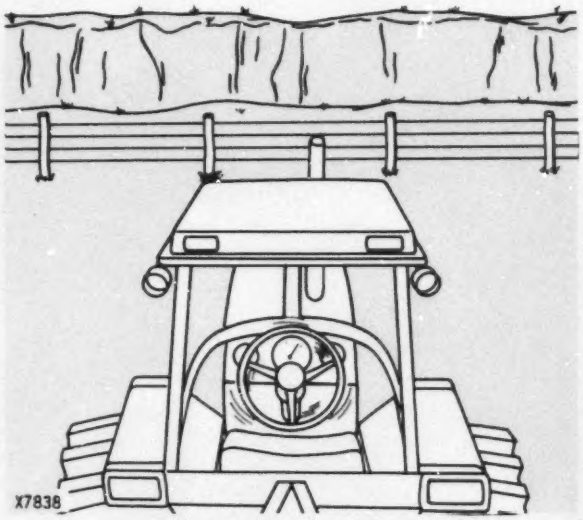

Fig. 6 — Fasteners Are Safety Devices

Think what would happen if someone forgot to install a small, cheap cotter pin in the steering mechanism of your car or tractor, permitting a nut to come loose and fall off! Certainly your safety would be in extreme jeopardy (Fig. 6).

FASTENERS MUST HAVE MANY QUALITIES

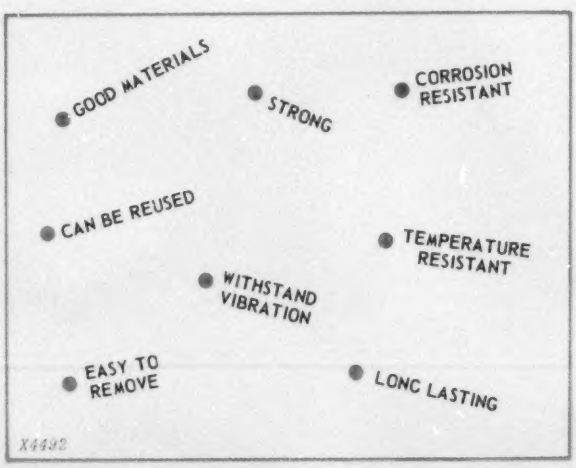

Fig. 7 — Some Requirements for Satisfactory Fasteners

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To do their job in modern products, fasteners must be carefully made out of high-quality materials. They must be strong enough to hold the components together, yet quick and easy to remove or install, and capable of being used over and over (Fig. 7).

Many fasteners must stand vibration without loosening, must be unaffected by extremes in temperature, must be corrosion resistant, and must last as long as the parts they join.

Because the right fastener is so important, a good mechanic will make sure that the ones he uses are of the right type, size and quality — and he will remove and install them in the correct manner, using proper tools. He'll read and follow all available service information, such as may be provided by the manufacturer in shop and technical manuals (Fig. 8).

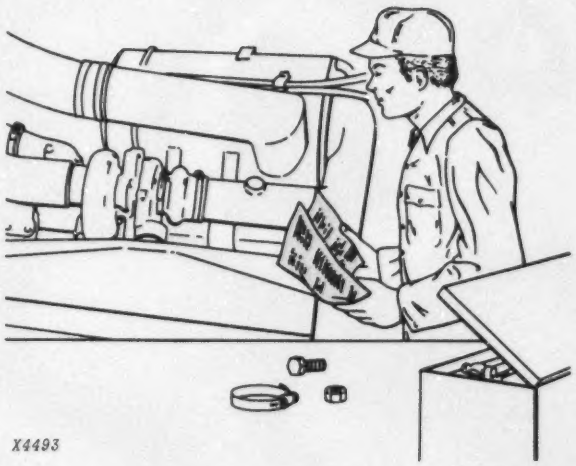

Fig. 8 — Read and Follow Instructions

TEST YOURSELF

QUESTIONS

1. Are bolts, buttons, and cotter pins fasteners?

2. What are three important functions that fasteners must perform?

3. Name three qualities that fasteners must have?

(Answers on page 71.)

Now let's take a look at the most common fasteners found in the home, on the farm, and in the shop.

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BOLTS, CAP SCREWS, NUTS, WASHERS, AND LOCKING DEVICES/PART 2

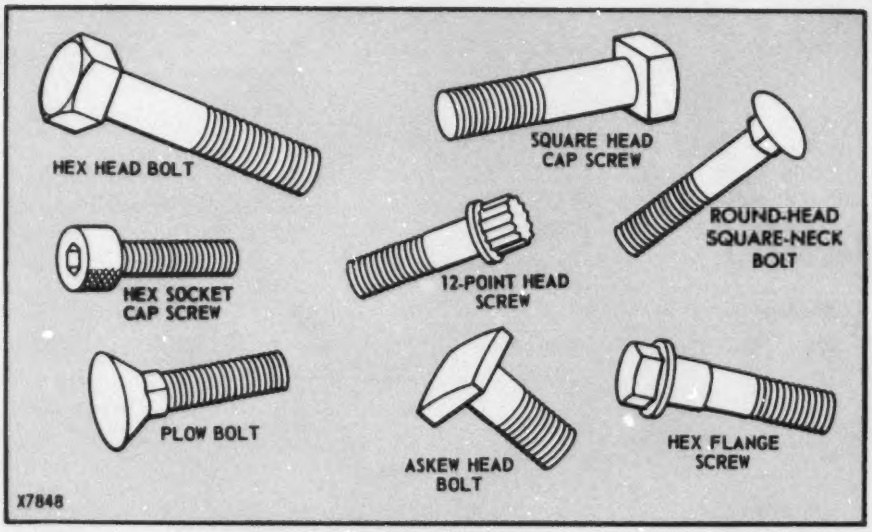

Fig. 9 — Typical Bolts and Cap Screws

Bolts, cap screws, and nuts are used as fasteners for a great number of mechanical devices. There follows a rather complete description of these versatile fasteners. Some of this information may seem rather rudimentary to you. But since this is a manual of "Fundamentals," such information must be included for those who may not be as familiar with fasteners as you are. It is hoped that what follows will be interesting and, perhaps, increase your fund of general knowledge. Also, many of the terms introduced apply equally to other types of fasteners and will not be repeated.

COMMON BOLTS AND CAP SCREWS

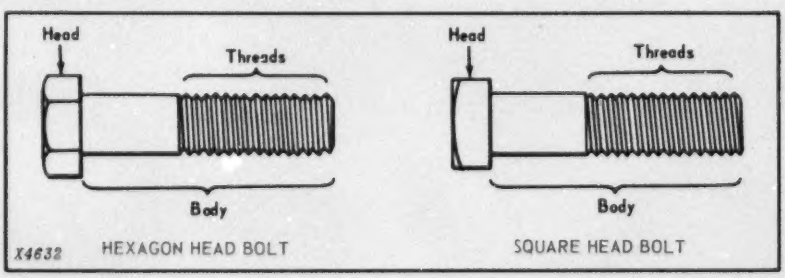

Fig. 10 — Bolt Parts

Bolts are usually used in plain holes drilled through the parts being fastened. The bolt is held in place with a mating nut. In contrast, cap screws are normally used in threaded holes, without a nut.

A **bolt** (or cap screw) is a length of metal rod with a head and a body (Fig. 10). The head is usually square or hexagonal (six-sided). In modern use most bolt have hex heads. The body of a bolt

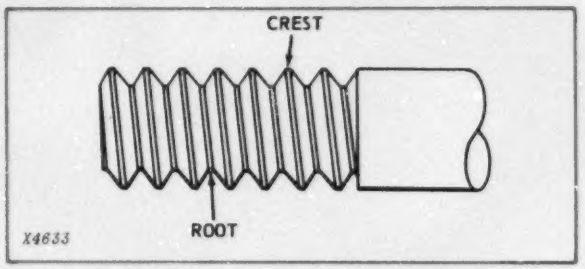

Fig. 11 — Names of Thread Parts

has external helical ribs, called *threads*, at the end opposite the head. The top of the rib is called the *crest*, or thread tip (Fig. 11). The bottom of the groove is called the thread *root*. Threads are made by cutting or by forming with a die (Fig. 12). Die-formed (or "rolled") threads are stronger than cut threads.

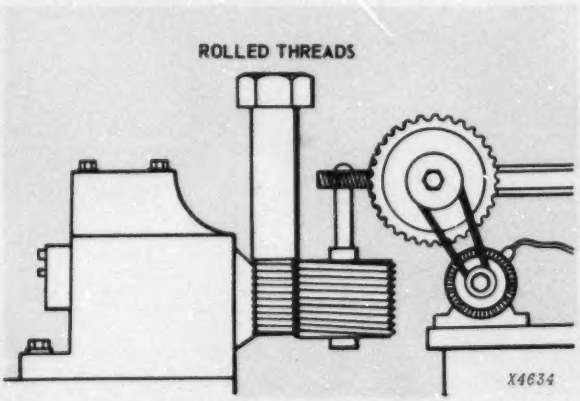

Fig. 12 — Die-Formed (Rolled) Threads are Best

Usually a bolt "mates" with internal threads of a *nut* (Fig. 13) which screws onto the threads of the bolt. For more about nuts, see page 12.

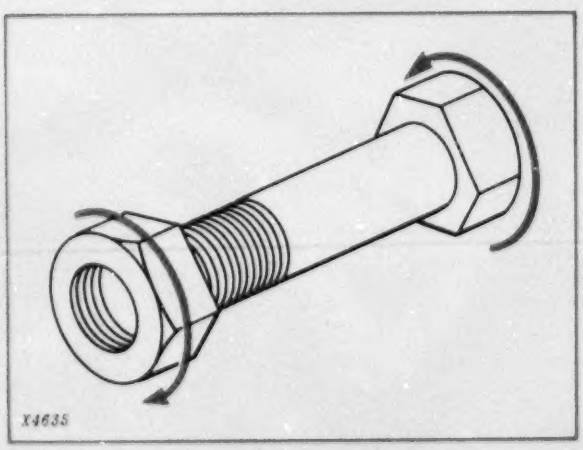

Fig. 13 — Bolt and Nut Combination

HOW TO MEASURE BOLTS

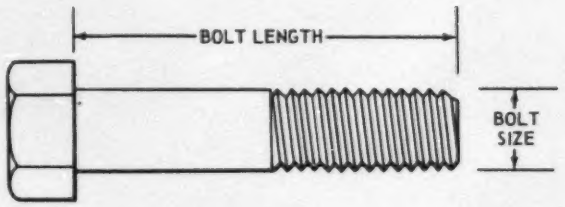

Fig. 14 — Where Bolts are Measured

The **size** of a bolt is determined by the diameter of the crest of the threads (Fig. 14).
The **length** of a common bolt is determined by measuring from the bottom of the head to the end of the threads.

NOTE: Some bolts (like flat countersunk head bolts, for instance) are measured slightly differently. See page 10.

The unthreaded part of the bolt is called the *body*.

The flattened point end of a bolt is normally pointed by rolling the first threads undersize at an approximate 45-degree angle.

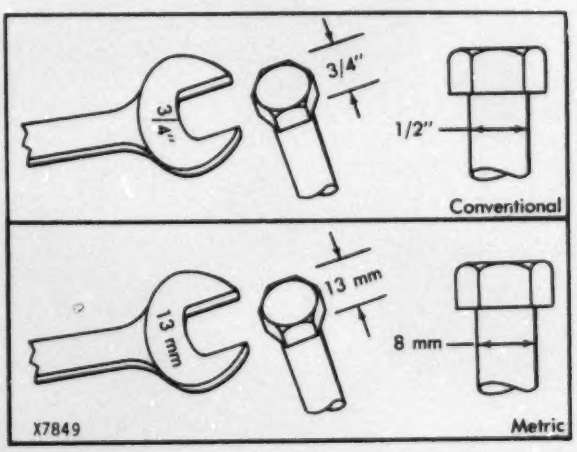

Fig. 15 — Selecting the Proper Wrench

A bolt head is measured across **flats.** Head size determines what size wrench or socket must be used to turn or hold the bolt. For example, a ¾-inch wrench (Fig. 15) is needed to turn a ½-inch bolt (a 13-mm wrench is needed to turn an 8-mm hex bolt or nut).

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THREADS

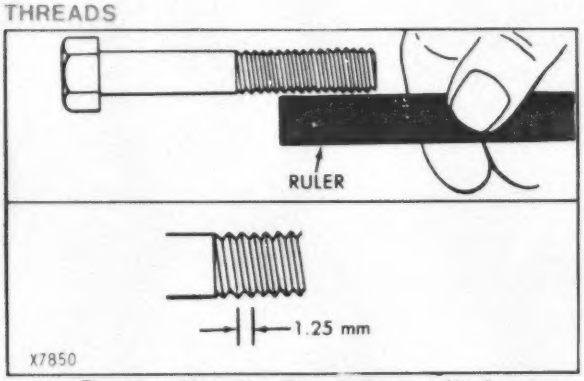

Fig. 16 — Measuring Threads Per Inch (Top) and Pitch (Bottom)

Threads are measured by counting the number per inch (Fig. 16). Threads on metric threaded fasteners are measured by the distance between threads (pitch) in millimeters (Fig. 16). Also, screw gauges are available that match the bolt threads against those on the gauge (Fig. 17); there is a separate gauge for each thread size.

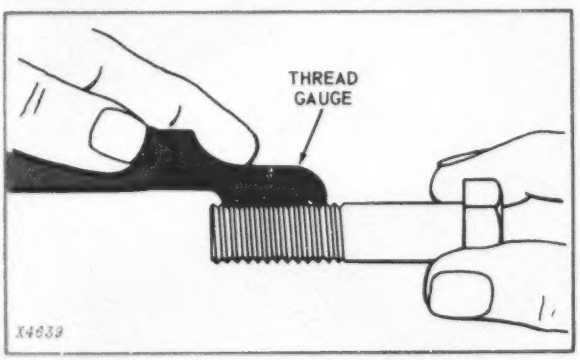

Fig. 17 — Using a Thread Gauge to Determine Threads Per Inch or Pitch

Some threads are coarse (Fig. 18) with deep grooves and are used for most applications. Other threads are finer, with shallower grooves. Bolts with fine threads are used only under special conditions where coarse-threaded bolts are not suitable. For example, when the parts being fastened have thin walls.

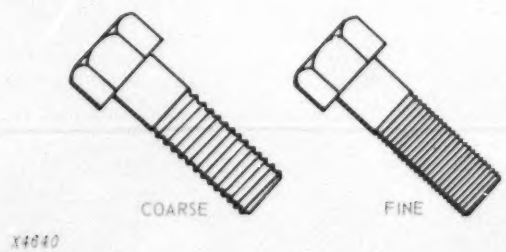

Fig. 18 — Examples of Coarse and Fine Threads

There are carefully controlled standards for threading bolts and nuts. These were developed by the American National Standards Institute (ANSI) and establish such things as the pitch (angle) of threads, the depth of the root, and manufacturing tolerances, or fit, designated by a thread class symbol, such as 1A, 2A, etc. The ANSI specifications are referred to as "Unified Screw Thread Standards." See Metric Thread Description below.

Have you ever seen a bolt or screw described like this?

½ — 20 UNC — 2A x 3

Perhaps you have wondered what the figures and letters mean. The simple chart below (Fig. 19) will help you understand them.

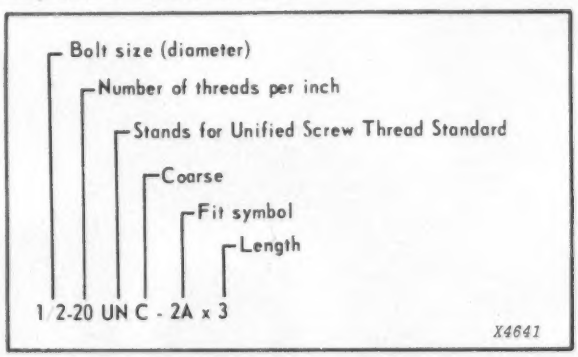

Fig. 19 — What Bolt Descriptive Symbols Stand For

In the above chart, if the bolt has *fine* threads, "UNC" would be replaced by "UNF."

In older publications you might find the phrase "½ — 20 NC (or NF) —" instead of UNC (or UNF). The NC and NF in these phrases stand for "American National Coarse" or "American National Fine" which was an earlier way of designating threads. However, since its adoption in 1948, the ANSI designation has replaced the earlier American National designation. Another earlier designation of coarse threads was U.S. Standard; fine threads were designated as S.A.E. Threads.

METRIC THREAD DESCRIPTION

The following chart shows how to describe metric threaded fasteners and what each letter and number represents.

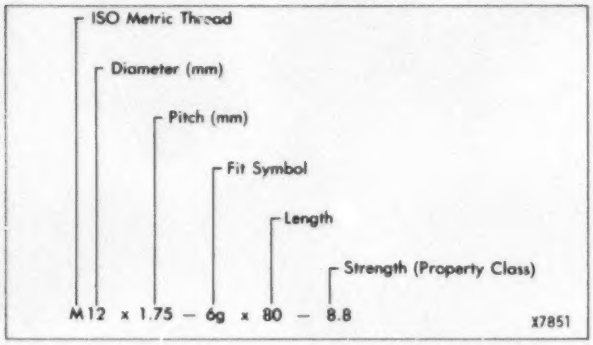

Fig. 20 — Metric Bolt Descriptive Symbols

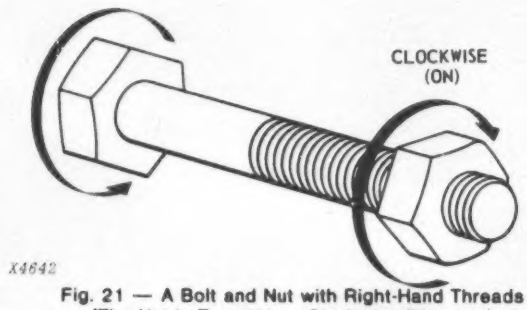

Fig. 21 — A Bolt and Nut with Right-Hand Threads (The Nut is Turned in a Clockwise Direction)

Bolts and screws normally have right-hand threads; that is, they are turned to the right in a clockwise manner when they are threaded into a nut or part (Fig. 21).

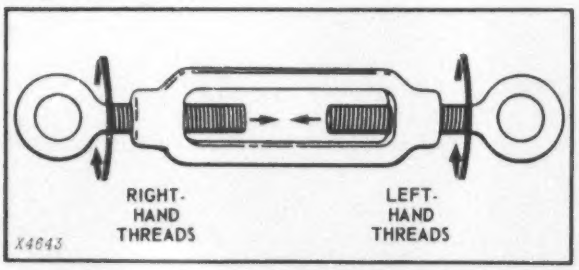

Fig. 22 — A Turnbuckle Has Both Right- and Left-Hand Threads

In a few rare cases, bolts, screws and nuts with left-hand threads are needed. A turnbuckle (Fig. 22) is one example of right- and left-hand threads in use.

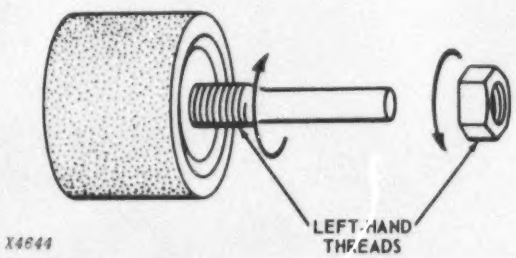

Fig. 23 — The Spindle and Nut on This Sanding Wheel Have Left-Hand Threads

Left-hand bolts and nuts are also used when rotary motion may tend to spin them loose. The spindle and nut of a sanding attachment (Fig. 23) for an electric drill is one example.

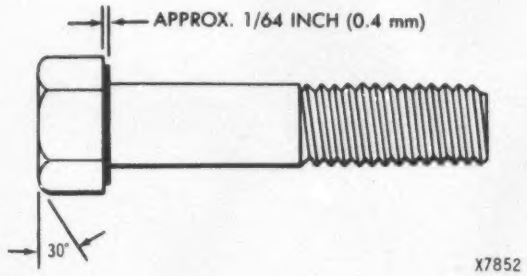

Fig. 24 — Washer Face Under Head of Bolt

Some cap screws have a circular bearing surface or washer face (Fig. 24) under the head. On other bolts a similar circular bearing surface is sometimes obtained by chamfering (bevelling) the corners on the undersurface of the head.

Many modern high-quality bolts and other fasteners are plated with a coat of zinc or cadmium for resistance to corrosion, and are sometimes dipped in chromate as further resistance to rust.

GRADES (OR PROPERTY CLASSES) AND HEAD MARKINGS

The kind of steel bolts and screws are made of and the treatment they receive during manufacture determine their strength and so their ability to do their job.

The Society of Automotive Engineers (SAE) has established certain standards for classifying unified (inch-series) bolts and screws into grades, based on their material and treatment and on their *tensile* strength. (Tensile strength is how much pull they can stand without breaking.)

For metric standards and property classes see discussion beginning on page 9.

The SAE has also designated markings to be put on bolt and screw heads to indicate the grade. The markings consist of radial *"slashes"*, and all high-quality inch-series bolts and screws ¼ inch and larger of recent manufacture have them.

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The chart below identifies the various grades, the head markings (slashes), composition, heat treatment, and tensile strength.

Most modern manufacturers are using Grade 5 or better hardware in their products. Even if grades lower than 5 are used in manufacture, Grade 5 or higher is usually specified for replacement.

SAE GRADE MARKINGS FOR STEEL BOLTS AND SCREWS

Grade Marking	Specification	Material	Tensile Strength min., psi.
	SAE-Grade 0	Steel	
	SAE-Grade 1	Low Carbon Steel	60,000
	SAE-Grade 2	Low Carbon Steel	74,000
	SAE-Grade 5	Medium Carbon Steel, Quenched and Tempered	120,000*
	SAE-Grade 7	Medium Carbon Steel, Quenched and Tempered	133,000
	SAE-Grade 8	Medium Carbon Alloy Steel, Quenched and Tempered	150,000

*Small size bolts. Larger bolts may have lower values.

X7853

Fig. 25 — SAE Grade Markings and Strength Specifications

METRIC GRADES (PROPERTY CLASS) AND HEAD MARKINGS

The International Organization for Standardization (ISO) has established standards for classifying metric bolts and screws into property classes. These classes are based on strength (tensile and yield). Markings (numbers) on the head indicate property class. All high quality metric bolts and screws larger than 4 mm have these markings.

The chart on page 10 (Fig. 26) identifies various grades, head markings (numbers), and tensile strength.

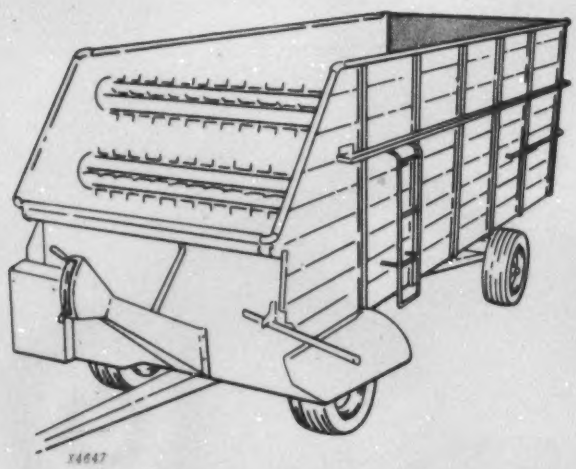
ISO PROPERTY CLASS MARKINGS FOR STEEL METRIC BOLTS AND SCREWS				
Grade Marking	Specification	Size	Tensile Strength MPa	Approximate Equivalent To Customary Fasteners
4.6	Class 4.6	M5 and larger	400	SAE Grade 1
4.8	Class 4.8	Up to M16	420	
5.8	Class 5.8	M5 to M24	520	SAE Grade 2
8.8	Class 8.8	Up to M16	800	SAE Grade 5
		Over M16	830	
9.8	Class 9.8	Up to M16	900	Nine percent stronger than SAE Grade 5
10.9	Class 10.9	Up to M36	1040	SAE Grade 8

X4646

Fig. 28 — ISO Property Class Markings and Strength Specifications

ROUND-HEAD BOLTS

Round-head bolts are used to fasten wood parts (Fig. 27) or steel parts with square punched holes. Most have a round (button) head (A, Fig. 28) with a square neck under the head. The neck prevents bolt rotation by sinking into the wood or square hole.



X4647

Fig. 27 — Many Carriage Bolts are Used to Assemble This Farm Chuck Wagon

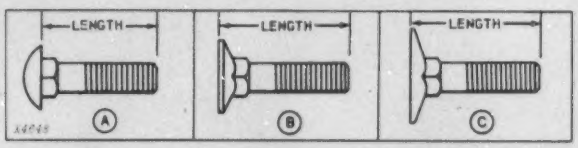


Fig. 28 — Round-head Bolt Head Styles

Some round-head bolts have round, countersunk heads (B, Fig. 28) for use when the top of the head must be flush with the surface of the wood or steel. Flat head bolts with a head diameter about three times that of the body are called "elevator bolts" (C, Fig. 28).

Like regular bolts and cap screws, the specifications for round-head bolts are established by ANSI and all high-quality bolts conform to these specifications.

The length of round head square neck bolts is measured from the threaded end to the *bottom* of the head.

Flat countersunk head bolts are measured from the threaded end to the *top* of the head (Fig. 28).

PLOW BOLTS

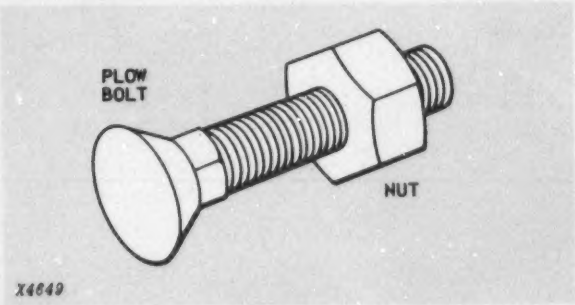


Fig. 29 — A Typical Plow Bolt with Nut

Plow bolts (Fig. 29), as their name implies, were developed to fasten plow shares and other parts to the plow *moldboard* (Fig. 30). They have flat, tapered heads that fit into countersunk holes in the share or other part. When the bolts are installed, the heads lie flush with the surface of the part, permitting earth to pass smoothly without obstruction.

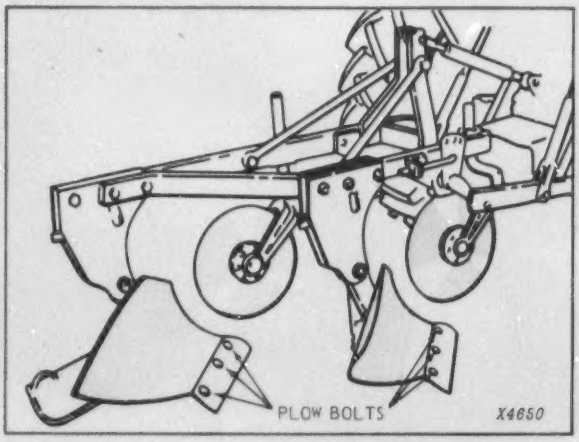


Fig. 30 — Plow Bolts are Used to Attach a Plow Share to Its Moldboard

Plow bolts are also used to attach the blade to such machines as bulldozers and motor graders (Fig. 31) which require earth to roll smoothly over fastened parts.

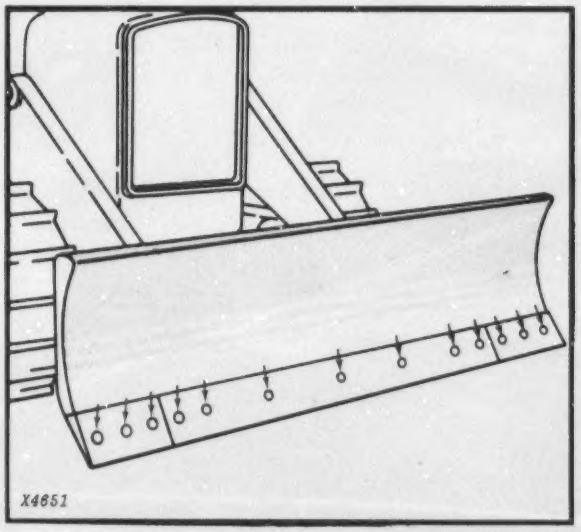


Fig. 31 — Plow Bolts are Used to Fasten the Cutting Edge to This Bulldozer Where Earth Must Pass Freely over the Blade

There are several styles of plow bolt heads, each style being identified by a number. For instance:

- No. 3 designates a flat, round, tapered head with a square shoulder under the taper. This is the bolt used most. See Fig. 32, next page.
- No. 4 designates a square, tapered head without the square shoulder.
- No. 7 designates a round, tapered head with a "key" projecting out from the taper.

Designations for metric plow bolts:

- 90° countersunk square neck bolt is roughly equal to No. 3.
- Countersunk reverse key head bolt is roughly equal to No. 7.
- No metric counterpart for No. 4.

Numbers are not used to designate metric plow bolts.

Plow bolts are available with coarse or fine threads, and conform to ANSI specifications and SAE Grades as to material, treatment and strength. (See page 7.)

The length of a plow bolt is measured from the end of the threads to the largest diameter of the head-bearing surface.

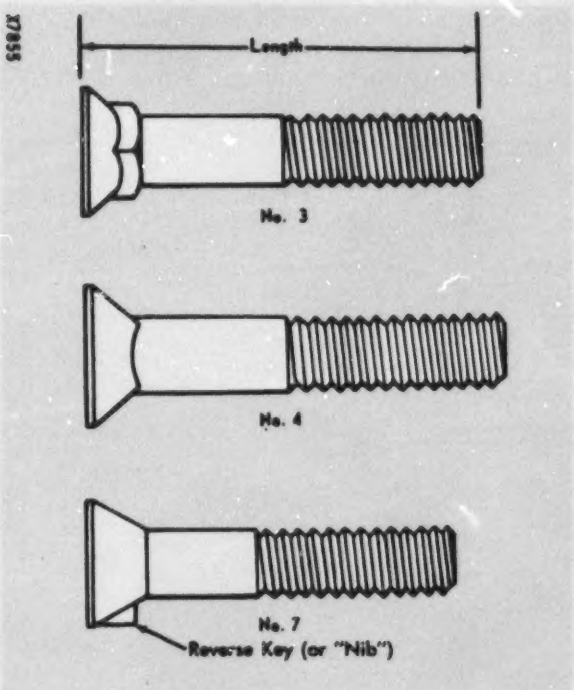


Fig. 32 — Typical Plow Bolt Head Styles

HEX SOCKET CAP SCREWS

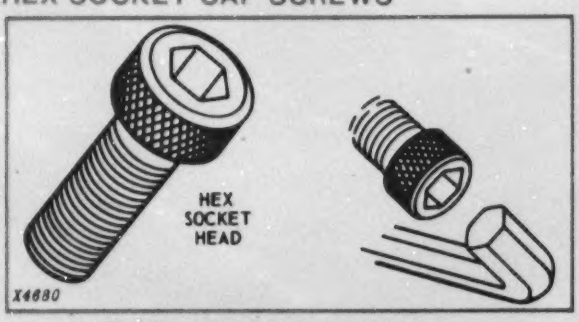


Fig. 33 — Hex Socket Head Cap Screw

Hex socket cap screws (Fig. 33) are sometimes used in recessed (sunken) holes (Fig. 34) or in confined spaces where the small head size is an advantage.

The head of a hex socket cap screw is the same size as the washer face on a hex cap screw of a corresponding size. Its head has a hex hole for a hex (Allen) wrench. Wrench size varies with cap screw size.

NOTE: Information in the preceding paragraph is not applicable for metric socket screws.

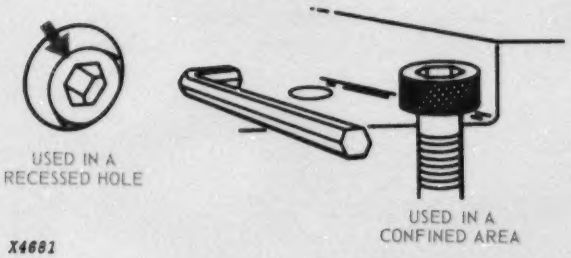


Fig. 34 — Hex Socket Head Cap Screws are Handy in Recessed Holes or Confined Spaces

12-POINT FLANGE HEAD SCREWS

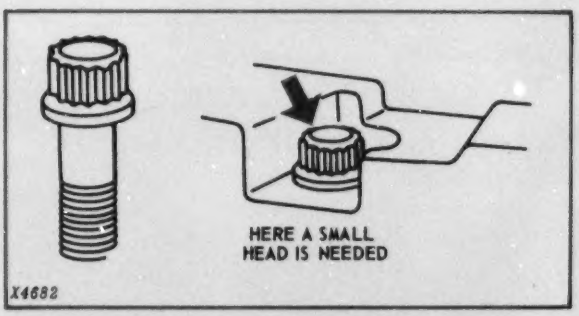


Fig. 35 — 12-Point Head Screw

These high-strength screws (Fig. 33) are turned by gripping external teeth around their heads. They are used where high-strength screws with small heads are required (Fig. 35).

12-point head screws are identified by diameter, screw length and body length in the same manner as standard hex head screws (Fig. 36). They can be turned by means of a small double hex socket (page 24) or a 12-point box-end wrench. Special sets of 12-point head screw sockets are also available.

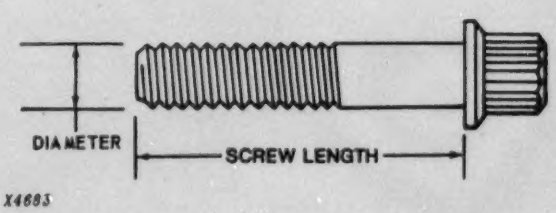


Fig. 36 — 12-Point Head Screw Dimensions

NOTE: Broken bolts and cap screws can be removed by tools usually called "stud drivers." For information on these tools see page 42.

NUTS

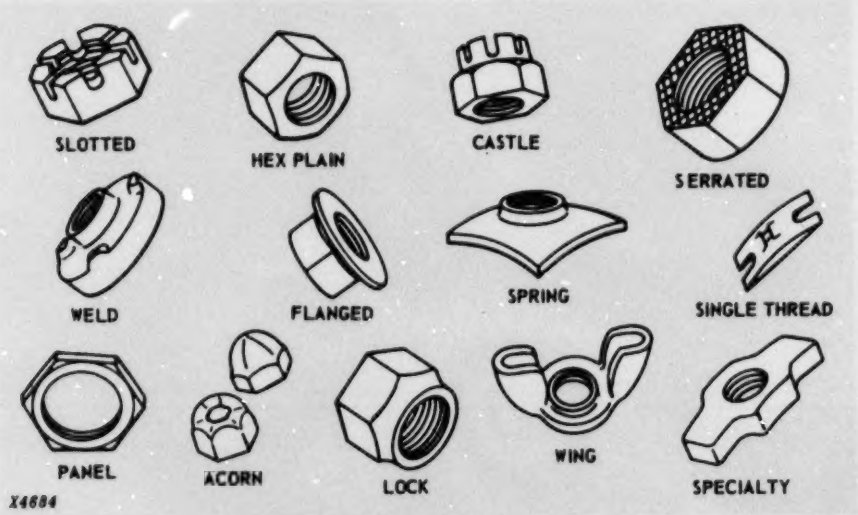


Fig. 37 — Typical Nuts

Most everyone is familiar with the nuts that screw onto a bolt.

There are literally hundreds of nuts of all shapes and sizes for special applications (Fig. 37). To cover them all is far beyond the scope of this book. Those discussed are the ones you are most likely to encounter.

HEX AND SQUARE NUTS

The most common nuts are made of steel and are hexagon or square. They have coarse or fine internal threads that correspond to those of the bolt. Threads per inch can be determined with a screw gauge (Fig. 38) just like bolt threads are measured.

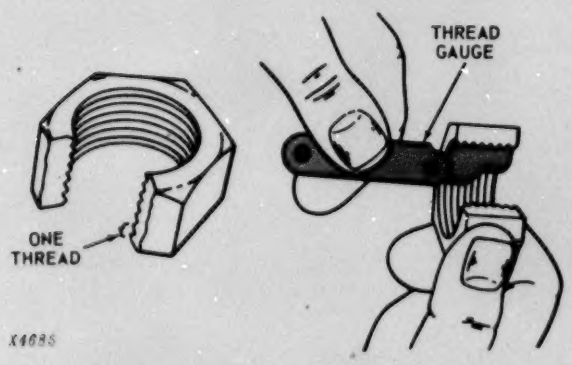


Fig. 38 — Determining Threads Per Inch with a Thread Gauge

The corners of some nuts are chamfered (beveled) (Fig. 39) on one side. Other nuts have chamfered corners on both sides so they can be installed with either side down.

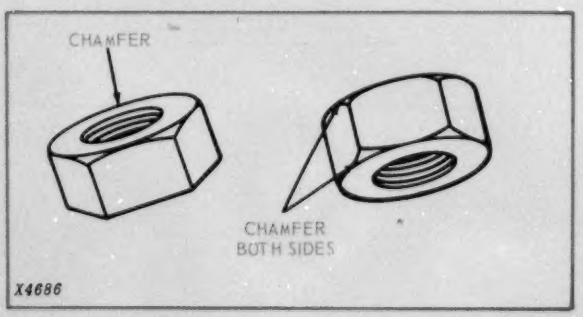


Fig. 39 — Most Nuts Have Chamfered Corners, Both Sides

The American Society for Testing and Materials (ASTM) and SAE are responsible for material and strength standards for unified (inch) nuts. ISO and ASTM establish standards for property classes for metric nuts. Normal metric nuts, used in the U.S.A., are classed as 5, 9, and 10. These numbers indicate the highest tensile strength of screw or bolt on which they should be used to avoid stripping.

Nuts have three important dimensions: (1) thickness, (2) distance across flats, and (3) inside diameter, which is the same as that of the bolt with which it is to be used.

JAM NUTS (INCH SERIES) "THIN" NUTS (METRIC)

One way to lock a threaded part in place is with a jam nut. Usually a jam nut is thinner than a "full" nut, but otherwise it is much the same as a full nut.

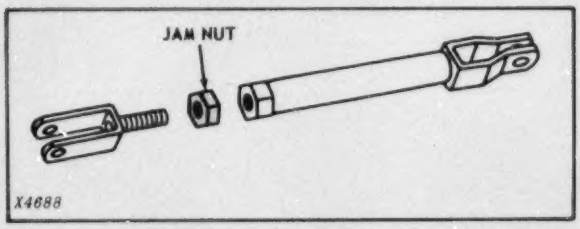


Fig. 40 — Location of a Jam Nut

A common application of jam nuts is on control linkage, such as the steering tie rods on a car or tractor, or the lift linkage (Fig. 40) on a modern chisel plow, which has to be adjusted for length. Once the adjustment is made, the jam nut is tightened against the rod end to lock the adjustment.

Metric property classes for thin nuts are 04 and 05 — 05 is heat treated. These nuts are not capable of developing the full load in a bolt or screw.

CASTELLATED AND SLOTTED NUTS

There are many applications where it is necessary to secure a nut in place so it can't possibly come loose. For this purpose castellated and *slotted* nuts are available.

The name for castellated nuts (commonly called *castle* nuts) comes from the fact that they resemble the battlements on an old feudal castle (Fig. 41).

Fig. 41 — The Battlements on a Castle

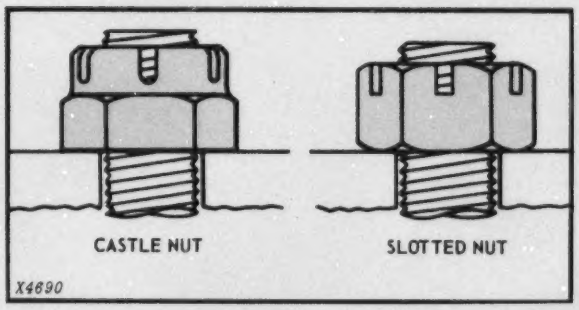


Fig. 42 — Castle and Slotted Nuts

As you can see from the above illustration (Fig. 42), the top part of a castle nut is smaller in diameter than the body of the nut. **(It should be noted that castle nuts are no longer standard in U.S.A.)** A slotted nut is simply a hex nut with slots.

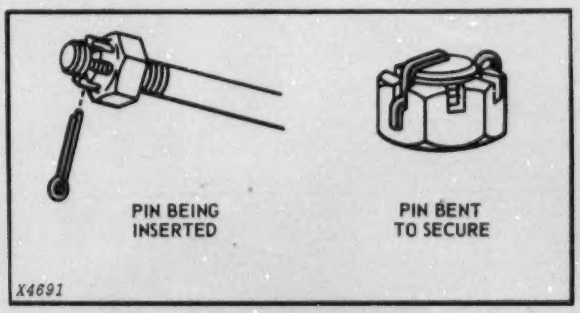


Fig. 43 — How a Cotter Pin is Used to Secure a Castle or Slotted Nut

Both nuts are used with bolts having a hole drilled through the end. When the nut is tightened onto the bolt, a cotter pin (Fig. 43) is inserted through the slots and hole to hold the nut firmly in place. (For more about cotter pins, see page 19.)

Castle and slotted nuts are identified by thickness and width across flats as well as by thread diameter and thread count (pitch).

SELF-LOCKING NUTS

Some nuts, once tightened, stay firmly in place because of the way they're made.

There are many types of these lock nuts, utilizing many ingenious means of staying tight. The ones that are most commonly used are called *prevailing-torque* and *plastic-insert* nuts. (Often referred to by their trade name "elastic" nuts.)

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Prevailing-Torque Nuts

A *prevailing-torque* nut is, by definition, one that is "frictionally resistant to rotation due to a self-contained prevailing-torque feature." This simply means that they grip the mating threads. There are many ways of doing this.

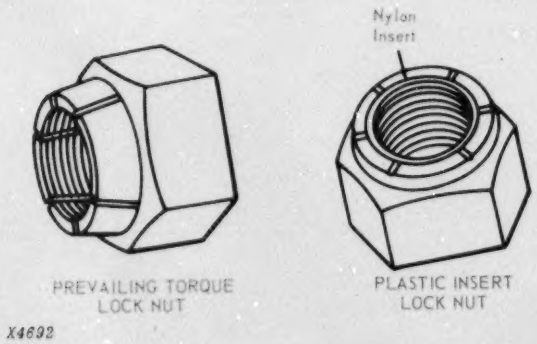

Fig. 44 — Prevailing-Torque and Insert-Type Self-Locking Nuts

One popular prevailing-torque nut (Fig. 44) resembles a castle nut, but the top is split into sectors bent inward. When the nut is threaded onto a bolt, the sectors are forced outward and grip the bolt tightly.

Prevailing-torque nuts can be reused over and over.

Plastic Insert Nuts

These nuts (Fig. 44), which are actually a special type of prevailing-torque nut, contain a relatively soft collar of unthreaded material built into the head. The collar may consist of suitable fibrous material or a plastic such as nylon.

When the nut is threaded onto a bolt the threads are impressed into the collar. Being elastic, the collar has a tendency to return to its original shape when removed so this nut can be reused many times.

Another feature of self-locking nuts is their ability to seal out moisture.

OTHER NUTS

As mentioned before, there are many other types of nuts available for special uses. You're probably familiar with *wing* nuts, *crown* nuts (also called cap or acorn nuts), single-thread nuts, and a host of others that you probably will seldom see. Fig. 45 shows just a few of these, many of which have self-locking features.

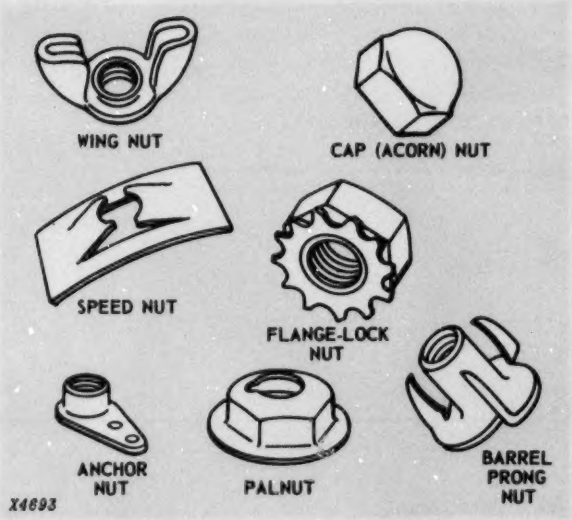

Fig. 45 — A Few Special-Purpose Nuts

CHEMICAL NUT LOCKS

Regular nuts can be locked in place with a liquid lock ("Loctite", for instance) to prevent loosening, especially from vibration. Most chemical locks (Fig. 46) are free-flowing plastic material. When applied to threads, the lock will fill the spaces between them and hardens, raising the "break loose" torque.

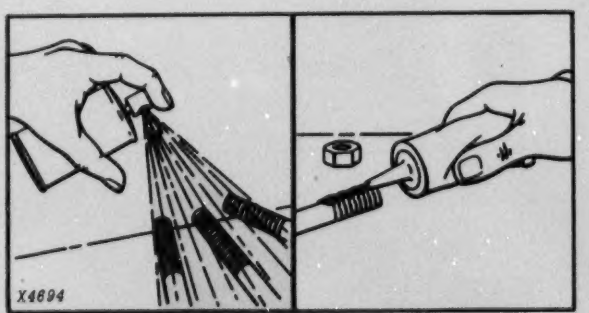

Fig. 46 — Sealants and Primers for Nuts and bolts

A primer should always be sprayed on the threads to clean them and speed up the drying time of the chemical lock.

Although chemical locks are excellent for keeping nuts and bolts tight, the bond can be broken, if necessary, for nut or bolt removal.

REMOVING STUBBORN NUTS

Sometimes, due to dirt, rust, or other corrosion, nuts become very difficult to remove. Some shops have a power impact wrench that can be used to loosen these hard-to-remove nuts.

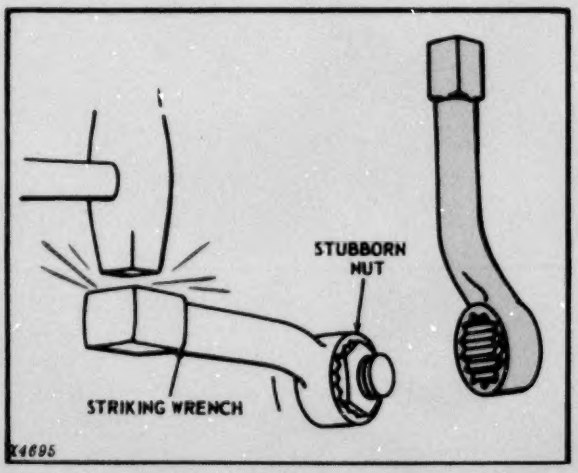

Fig. 47 — Using a Striking Wrench to Remove a Stubborn Nut

If you don't have an impact wrench, and the location of the nut permits, try a striking wrench as shown in Fig. 47.

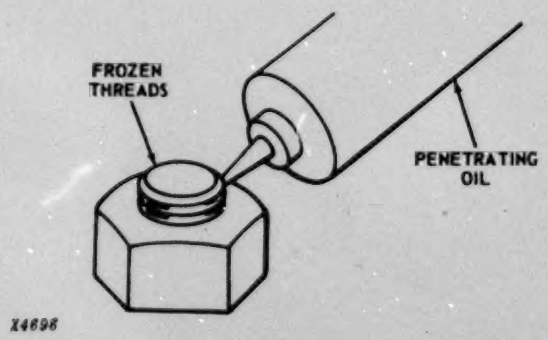

Fig. 48 — Penetrating Oil is Often Helpful in Removing Nuts

Sometimes hard-to-get-to nuts (and bolts) can be loosened with penetrating oil (Fig. 48) or special liquids made for this purpose.

Heat (Fig. 49) can also be used. However, heat can destroy any heat treatment of a hardened bolt or nut, as well as that in the surrounding area, so gas torches should be used judiciously. Also, always bear in mind the fire hazard they might create.

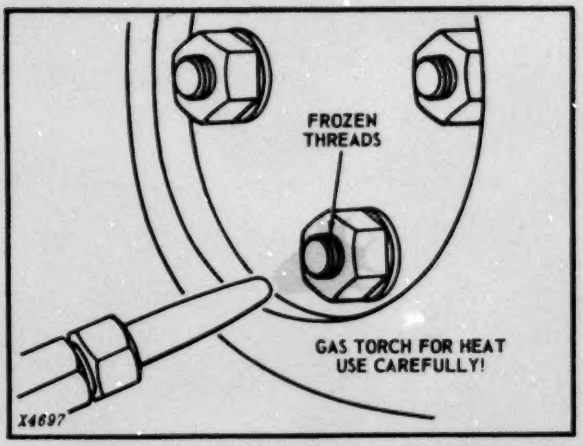

Fig. 49 — Heat is Often Helpful *BUT* Use It Wisely!

Stubborn nuts can be cracked off with a clamp-like device called a *nut-splitter* (Fig. 50) that contains a sharp, chisel-like tooth.

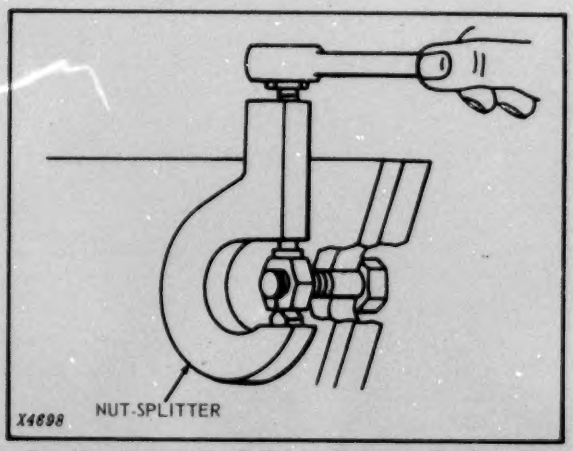

Fig. 50 — Using a Nut Splitter to Remove a Stubborn Nut

If all else fails, a sharp chisel or hacksaw (Fig. 51) can be used, if care is taken not to damage other parts.

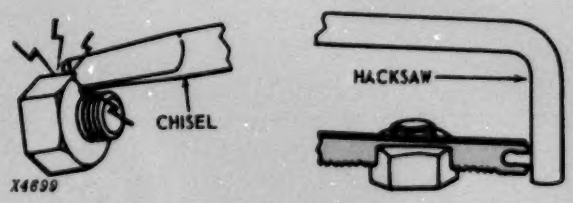

Fig. 51 — Using a Chisel or Hacksaw to Remove a Nut

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RESTORING THREADS

Even though you try to be careful, sometimes threads may be damaged when work is done. If no replacement is readily available, threads may be touched up and small nicks or burrs removed.

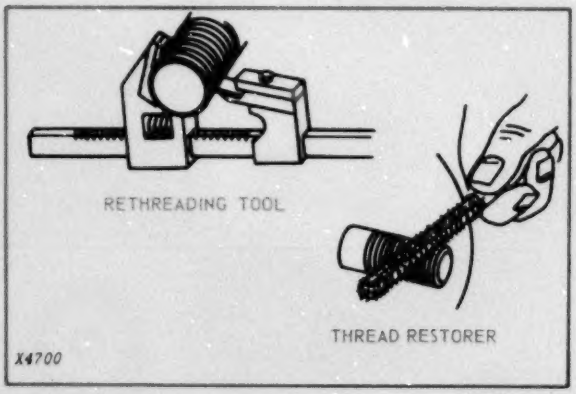

Fig. 52 — Using a Rethreading Tool and Thread Restorer

This can be done with a *rethreading tool* (Fig. 52). A file-like *thread-restorer* can also be used.

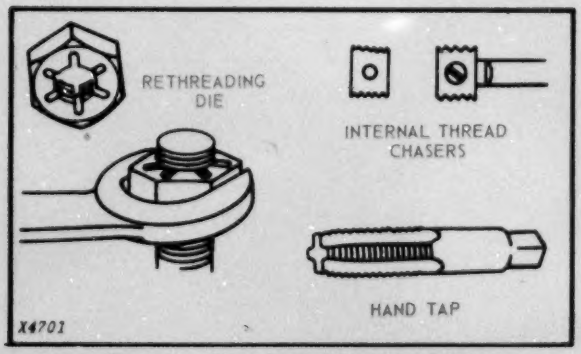

Fig. 53 — Other Thread-Restoring Tools

Another means of cleaning or restoring bolt and stud threads is a rethreading die of the proper size (Fig. 53). Internal holes can be recut with an internal thread chaser (Fig. 53) or hand tap.

NOTE: More information on proper techniques for installing, removing, and tightening nuts is given beginning on page 21 of this manual.

WASHERS

PLAIN WASHERS

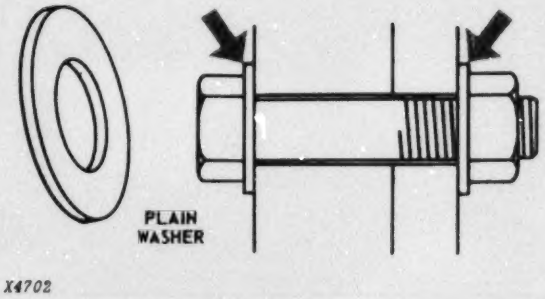

Fig. 54 — A Flat Steel Washer

A plain washer (Fig. 54) is simply a steel disk with a hole through the center. Though simple parts, washers are very important in many applications.

When used under the head of a bolt, or under a nut (Fig. 54), a plain washer distributes the load over an area larger than the head of the bolt or nut, thus reducing the stresses that would otherwise exist. Washers also protect the surfaces of fastened parts from damage which might occur without them when a bolt is tightened.

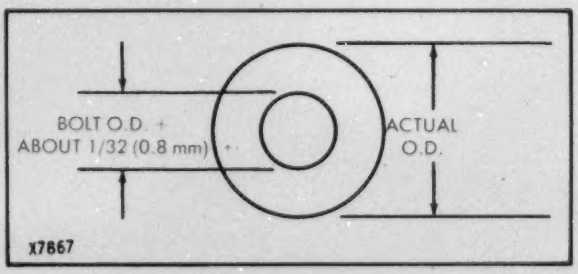

Fig. 55 — How Flat Washers are Measured

Plain washers are identified by their outside diameter and diameter of the hole which is the *bolt* size rather than the actual diameter of the hole. The hole is a little oversize [$\frac{1}{64}$ to $\frac{1}{8}$ inch (0.4 to 3 mm)] (Fig. 55) so the washer will slide easily over the body of the bolt.

Usually washer thickness is given in decimal portions of an inch or in millimeters (i.e., .060 inch, 1.6 mm). Sometimes inch-size washer thickness is specified by the *gauge* of the steel from which it is stamped. The larger the gauge number, the thinner the washer. For instance, washers stamped from 16-gauge steel are 0.0598" thick; 10-gauge washers are 0.1345" thick. Some typical metric washer thicknesses in mm are 0.5, 1, 1.2, 1.6, 2, 2.5, 3, 4, and 5.

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LOCK WASHERS

Helical Spring Washers

A frequently used method of keeping nuts and bolts tight, especially when they are subject to machine vibration, is the use of helical spring washers.

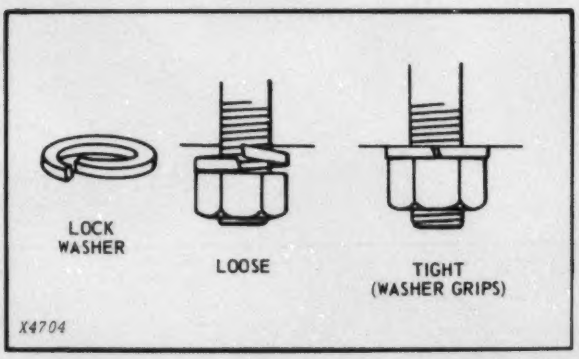

Fig. 56 — A Helical Spring Washer and How it Works

These washers (Fig. 56) are made of tough, spring steel. At one point they are split and one end of the split is bent up.

Usually lock washers are placed under a nut (Fig. 56) but they can also be used under a bolt head.

When the nut or bolt is tightened, the section of the washer that is bent up bites into the nut or bolt head and into the fastened part, helping to keep the nut or bolt from turning.

Like plain washers, the inside diameter of lock washers is expressed by screw diameter, rather than the washer inside diameter which is slightly larger so the washer will slide easily over the bolt.

Lock washers smaller than ¼-inch inside diameter are identified by numbers, the same as those used to identify machine screws which are discussed a little later in this manual. Metric lock washers are identified by nominal screw (thread) diameter in millimeters. See page 35.

Toothed Lock Washers

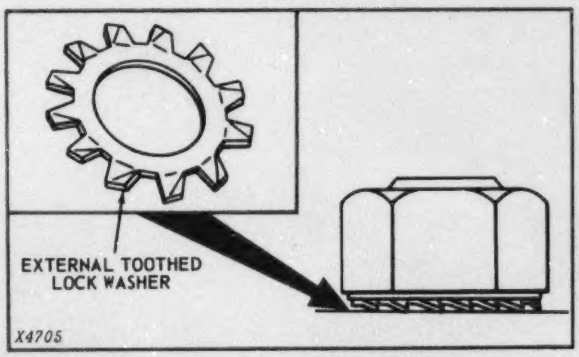

Fig. 57 — How a Toothed Lock Washer Grips

When special holding power is required, a toothed lock washer is often used because it has many sharp, heat-treated teeth to dig into the surfaces pressing against it (Fig. 57).

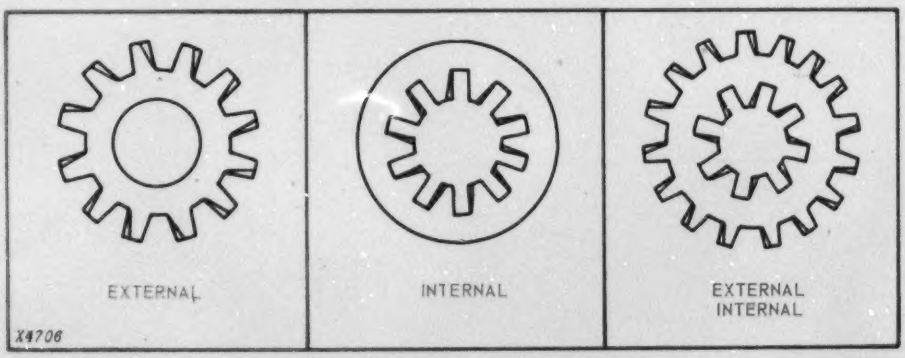

Fig. 58 — Toothed Lock Washer Styles

These washers (often known by their trade name, "Shakeproof") may have external (outside) teeth (Fig. 58) or internal (inside) teeth. Some have both internal and external teeth for extra holding ability.

Another common external tooth washer is cone-shaped for use with countersunk, flat-head screws (Fig. 59).

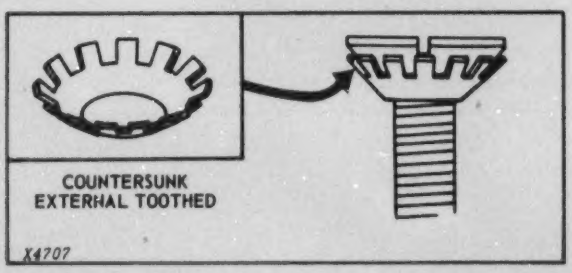

Fig. 59 — A Cone-Shaped External-Tooth Lock Washer

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Toothed washers are identified by bolt size. Like helical spring washers and machine screws, those under ¼-inch are designated by number. Metric toothed washers are designated by nominal screw (thread) diameter in millimeters.

There are many other toothed lock washers, developed for special applications, but they all work on the same principle.

COTTER PINS

Back on page 13 where castle and slotted nuts were discussed, cotter pins were mentioned. These simple pins are used to hold a nut and bolt tightly together and to keep the nut from coming off.

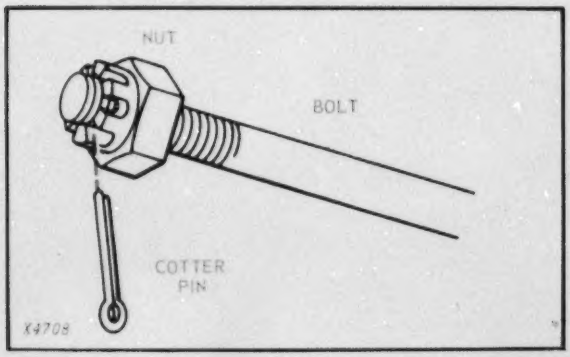

Fig. 60 — Relation Between a Cotter Pin, Nut, and Bolt

The cotter pin is slipped between the nut slots and through a hole in the end of the bolt (Fig. 60).

Cotter pins are made of soft metal so the prongs can be bent around the nut.

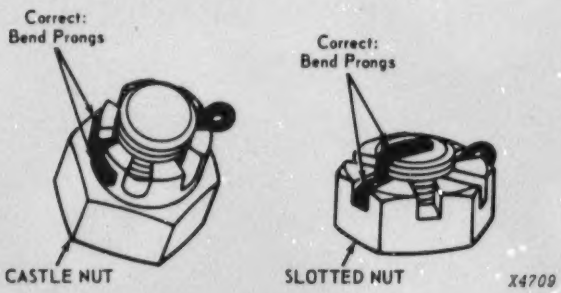

Fig. 61 — Cotter Pin Prongs Properly Bent Around a Castle Nut and a Slotted Nut

When used with a castle nut the prongs are usually bent back against the rounded nut top (Fig. 61).

When a cotter pin is used with a slotted nut (on an engine connecting rod, for instance), one prong is usually bent up and over the end of the bolt (Fig. 61).

If the hole in the bolt does not line up with the nut slots when the nut is tightened, the nut must be tightened just enough more so the pin can be inserted.

NOTE: Some bolts may have two holes for more precise adjustment.

IMPORTANT: Never LOOSEN a nut to align the cotter slot unless the instructions of the machine manufacturer say to do so.

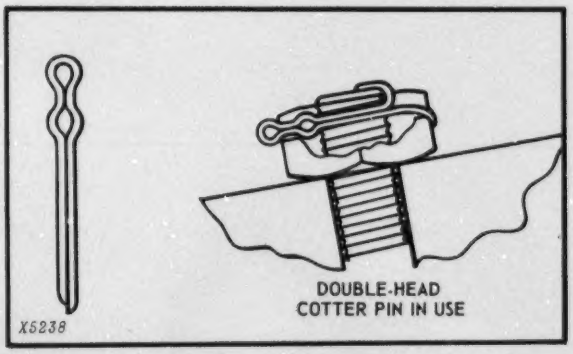

Fig. 62 — How a Double-Head Cotter Pin is Used

When installed, the eye of the cotter pin head is inside the nut slot. To make removal easier, a double-head cotter pin (Fig. 62) is sometimes used.

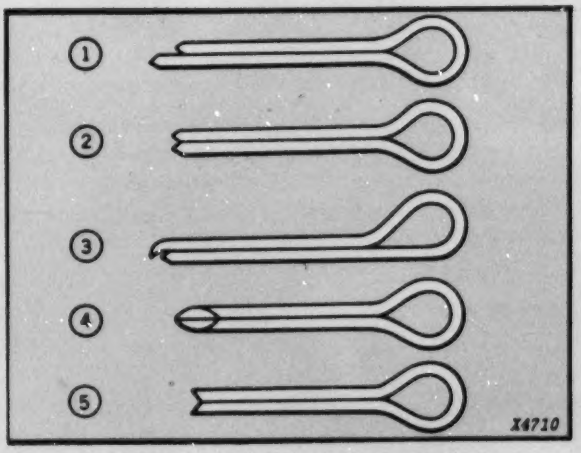

Fig. 63 — Common Styles of Cotter Pin Ends

A number of different point styles are available. Those which are considered more or less standard are shown in Fig. 63:

1 — Chisel point with extended prong for general use
2 — Chisel point with even ends
3 — Hammerlock type for castle nuts
4 — Taper pointed to align parts for quick insertion
5 — Internal V-cut type

The diameter of cotter pins is given in fractions of an inch; length is from the bottom of the head loop to the end of the *shortest* prong.

The diameter of a metric cotter pin is designated by the diameter of the hole (in millimeters) in which it will be used. Metric and inch-size cotter pins are often interchangeable — 1.6 mm and 1/16 inch, 3.2 mm and 1/8 inch, 6.3 mm and 1/4 inch.

LOCKWIRES

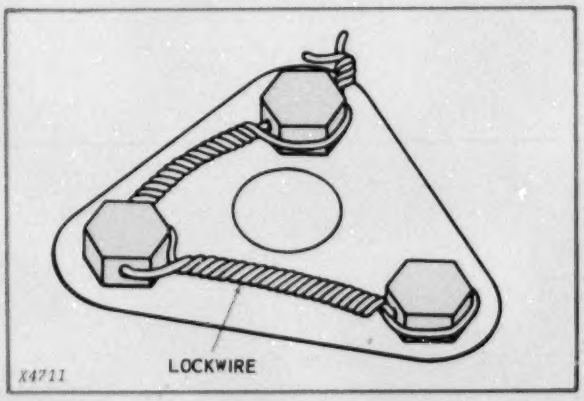

Fig. 64 — Lockwire Properly Installed

Sometimes *lock* or *safety* wire can be used to anchor bolts in place. The bolts for this purpose have holes drilled through their heads. The lockwire is pushed through the bolt holes (Fig. 64) and twisted in such a way that the wire will tighten if the bolt loosens.

Occasionally it is important to prevent unauthorized tampering with critical mechanisms or adjustments. In such a case a *seal* is attached to the lockwire as it is twisted; the seal must be broken before the lockwire can be removed.

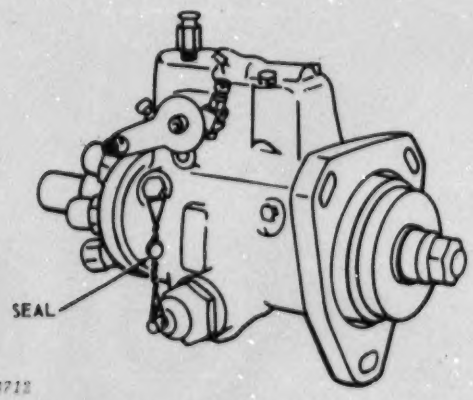

Fig. 65 — Sealed Lockwire on a Diesel Fuel Injection Pump

The diesel fuel injection pump (Fig. 65) on a modern tractor is a good example of the use of a lockwire with seal.

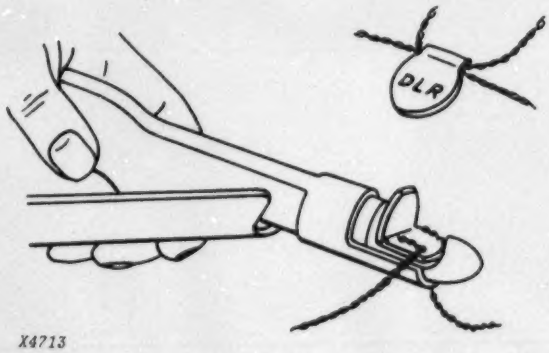

Fig. 66 — Using a Special Tool to Close a Lockwire Seal

A special sealing tool (Fig. 66) is used to close the seal after it is installed on the lockwire.

FLAT METAL LOCKS

Another way of locking bolts or nuts to keep them from turning is with *flat metal locks*. These are usually made of soft metal, although some are hardened. Some have special shapes for specific applications.

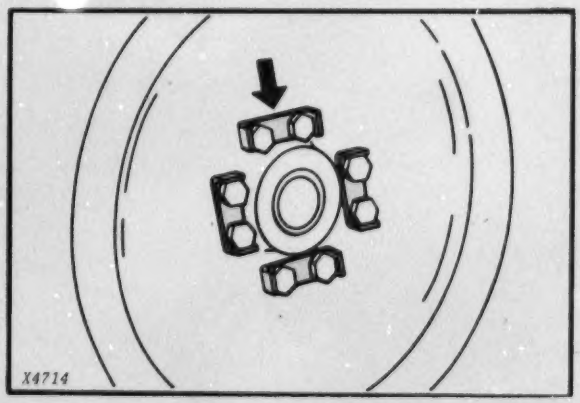

Fig. 67 — Flat Metal Locks Hold Flywheel Bolts in Place

One common usage for metal locks is for locking flywheel bolts (Fig. 67); the locks are placed under the bolt heads.

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Locks have *ears* that are bent up against one of the bolt head flats (Fig. 68) with a cold chisel or punch.

Some locks are placed on the corners of metal parts; these require that an ear be bent downward, too, against a flat edge — not a rounded corner, as shown in Fig. 68.

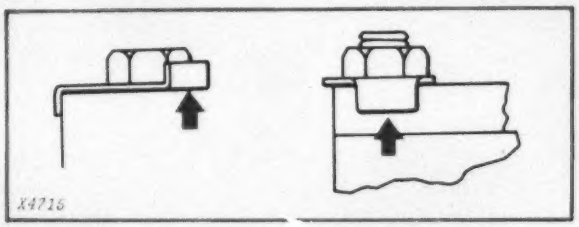

Fig. 68 — Lock Ears Properly Bent into Place

TEST YOURSELF

QUESTIONS

1. What are the two shapes of heads normally found on common bolts and cap screws?
2. Give the terms used to describe the top and bottom of bolt and screw threads.
3. How are threads measured? Metric threads?
4. Which is the higher strength bolt — one with 5.8 on the head or one with 8.8?
5. True or False? The tensile strength of an SAE-Grade 8 bolt is about 100,000 pounds per square inch.
6. As their name implies, plow bolts are used to assemble a plow share to the moldboard. What other machines use plow bolts?
7. What is a jam nut ("thin" nut) used for?
8. Name two types of self-locking nuts.
9. You've encountered a stubborn nut that can't be loosened with an ordinary wrench. What are two handy tools to remove it?
10. What is frequently used to keep a bolt or nut tight?
11. Chisel point, hammerlock, taper pointed and internal V-cut describe the end of one type of fastener. Name it.
12. Why is a seal sometimes attached to lock wire?

(Answers on page 71.)

WORKING WITH BOLTS, CAP SCREWS, AND NUTS/PART 3

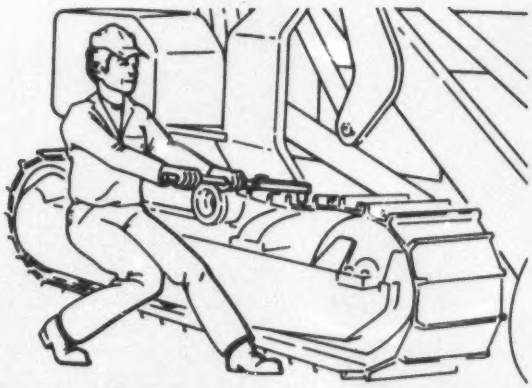

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Fig. 69 — Tightening Crawler Tractor Track Bolts

On ths previous pages you were introduced to these important fasteners — bolts, cap screws and nuts. But that's just part of the story. An equally important part is how to utilize them and treat them properly. The next few pages will give you some pointers on how to do this.

WRENCHES

Most fasteners would be useless without a quick, easy means of installing and removing them. Tool manufacturers have worked hand-in-hand with hardware manufacturers to develop tools for this purpose.

A good mechanic always selects the proper tool for the job. The right tool is usually the safest tool, too. And this includes wrenches (Fig. 70) for bolts, cap screws and nuts.

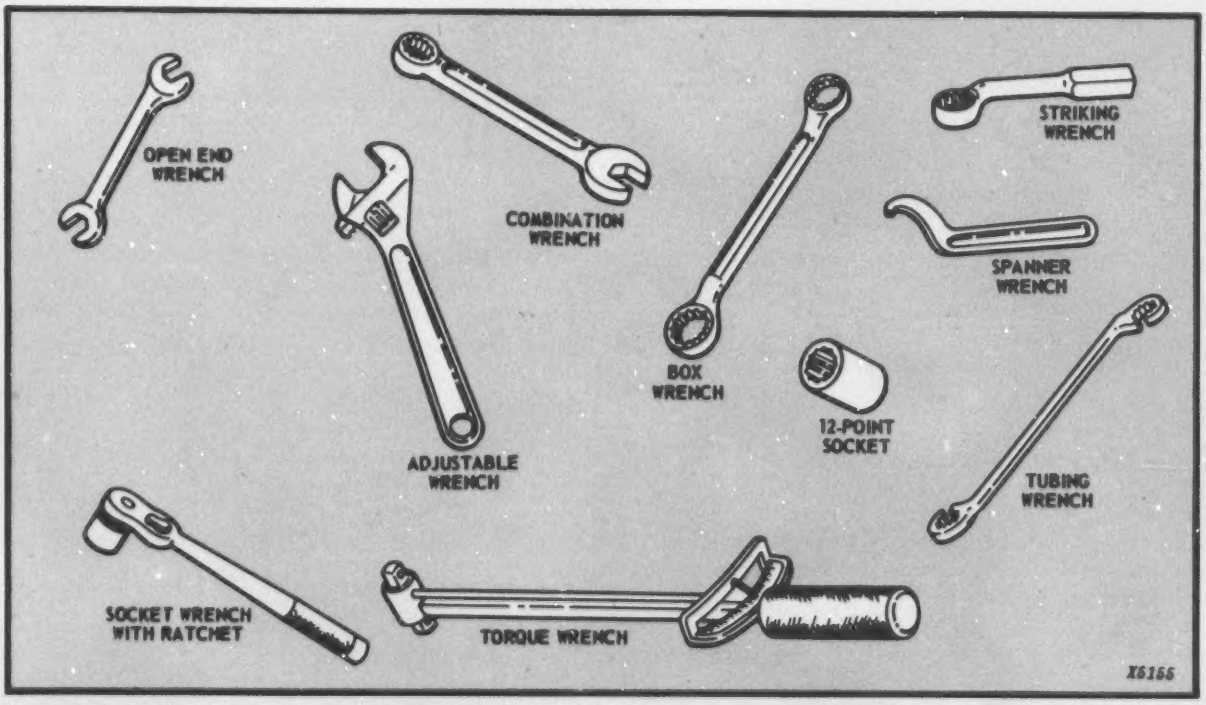

Fig. 70 — Common Wrenches for Bolts, Cap Screws, and Nuts

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OPEN-END WRENCHES

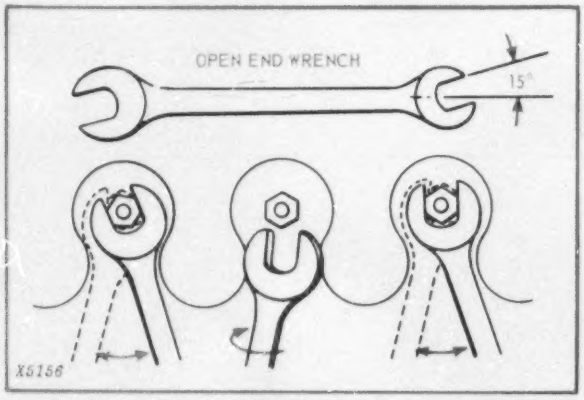

Fig. 71 — An Open-End Wrench and How to Use It

An open-end wrench (Fig. 71) has a jaw on both ends, usually of slightly different sizes; ½-inch and 9/16-inch, for instance (a metric open-end wrench may have jaws measuring 16 mm and 18 mm on each end). The sizes of the openings are the distances across the flats on the bolt head or nut; they are *not* the bolt diameter.

The head of an open-end wrench is normally offset at an angle of 15 or 22½ degrees to the body. You may wonder why it is made this way. The reason is that the offset allows you more swing space in close quarters by "flopping" the wrench as shown in Fig. 71.

BOX WRENCHES

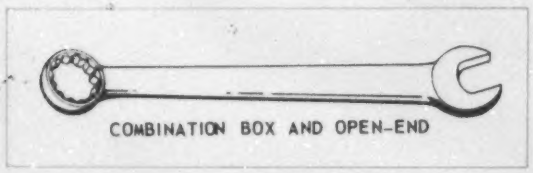

Fig. 72 — Box and Combination Wrenches

The openings on the ends of a box wrench (Fig. 72) completely surround the bolt head or nut thus providing a firmer grip than is possible with an open-end wrench.

COMBINATION WRENCHES

Combination wrenches with one box end and one open-end (Fig. 72) are available. These are handy because they speed up nut-and-bolt installations. You can use the box end to break loose or snug down a nut, for instance, then use the open end for greater speed the rest of the time.

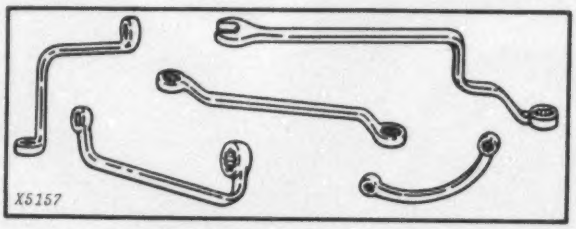

Fig. 73 — Variations of Box and Combination Wrenches

Open-end and box wrenches come in many different shapes and thicknesses (Fig. 73) for specialized jobs where nuts or bolts are difficult to remove with an ordinary wrench.

ADJUSTABLE OPEN-END WRENCHES

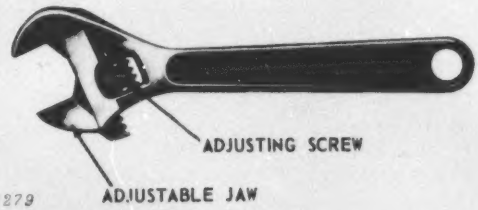

Fig. 74 — An Adjustable Open-End Wrench

This wrench (Fig. 74), best known by its trade name, "Crescent" is handy when an odd-sized bolt or nut is encountered.

An adjustable wrench is **not** intended to take the place of an open-end or box wrench, nor is it satisfactory for hard service. It's difficult to tighten sufficiently to prevent a certain amount of "give" as turning force is applied which is liable to distort or round off the corners of the bolt head or nut. Also, the wrench can be "sprung" by applying too much force. Treat it gently.

GOOD WRENCH PRACTICES

Though wrenches are simple tools, they must be used properly; otherwise results will be unsatisfactory in one way or another.

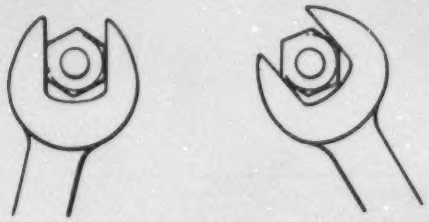

Fig. 75 — Correct Fit of Wrench on Nut is Important

1. Be sure the wrench fits snugly on the nut or bolt head (Fig. 75). A sloppy fit will round and burr the corners of the bolt head or nut.

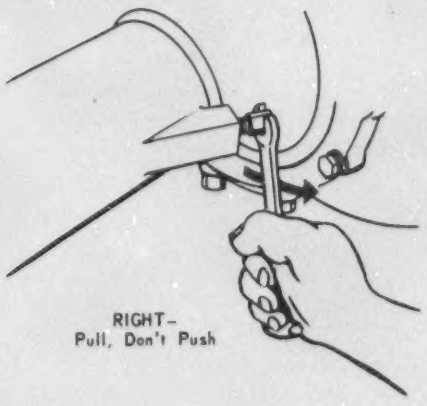

Fig. 76 — Always Pull on a Wrench — Don't Push

2. Always *pull* (Fig. 76) on a wrench — don't *push* — to keep your knuckles from getting scraped. If you must push, use the base of your palm and keep your hand open.

3. Never hammer on a regular wrench. If pounding is necessary to remove a stubborn part, use a heavy-duty striking wrench (Fig. 77) designed for use with a hammer.

4. Never use a bar or pipe to increase leverage on a wrench (Fig. 78); the extra twisting force will very likely damage or break something. The only

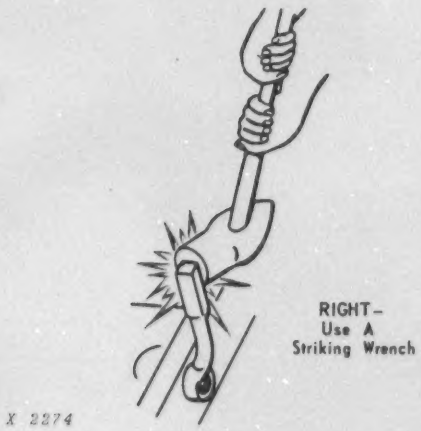

Fig. 77 — Never Hammer on a Regular Wrench

exception is when the work is hard to reach and you must use an extension.

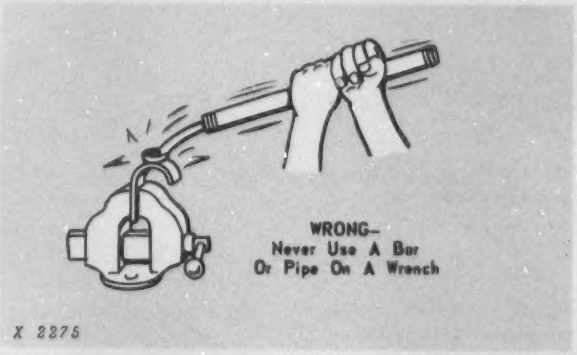

Fig. 78 — Using a Bar or Pipe on a Wrench is Bad Practice

5. Don't use makeshift tools such as pliers (Fig. 79). They won't tighten satisfactorily and will scuff and distort the nut or bolt head. Pliers are holding tools, not tightening tools.

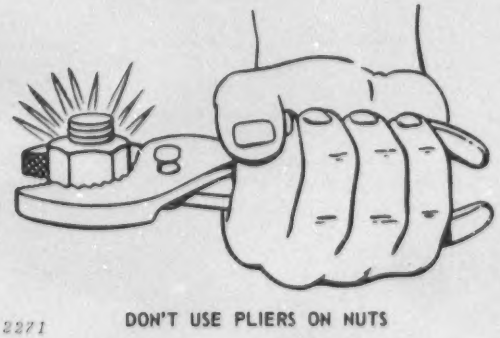

Fig. 79 — Wrong Use of Pliers

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SOCKET WRENCHES

Socket wrenches are a real boon to the mechanic and serviceman. They make his work easier and faster, and are often the only type of wrench that can be used in special situations. A full socket wrench set contains the sockets themselves and accessories to use them to best advantage.

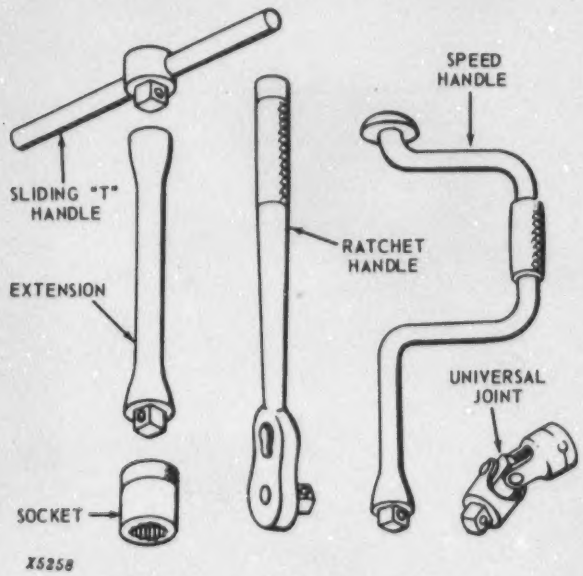

Fig. 80 — A Typical Socket Set and Handles

Fig. 80 shows a modern 12-point socket, a sliding T-handle, a speed handle. Combined in various ways, these socket sets can do many nut-and-bolt jobs.

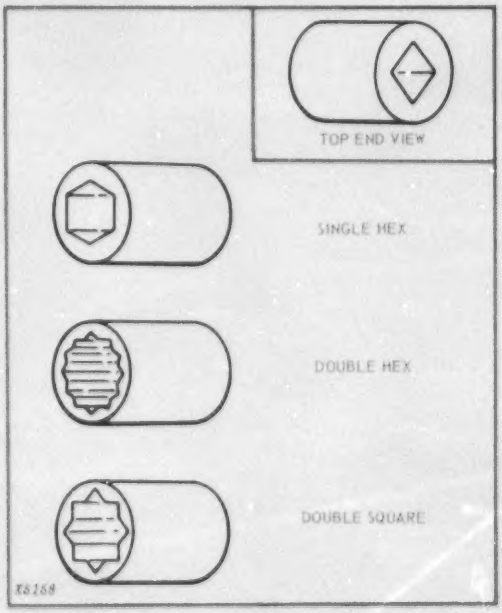

Fig. 81 — Types of Sockets

The sockets come in a wide range of sizes; some have six sides and are single-hex (Fig. 81). They fit snugly around a hex bolt head or nut. Others have 12 points or notches; these sockets drop more readily over the bolt or nut and are often called *double hex* sockets.

Square nuts or square-headed bolts require an 8-point or double square socket (Fig. 81).

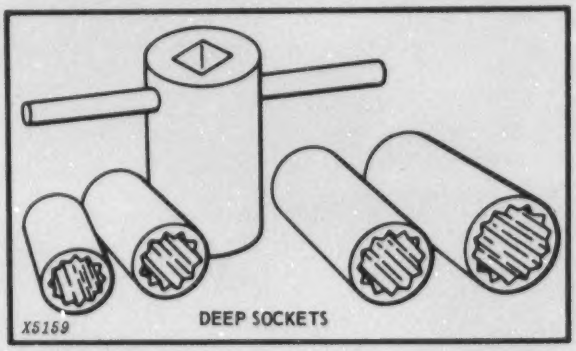

Fig. 82 — Special Deep Sockets

Extra deep sockets (Fig. 82) are available for use in removing spark plugs and nuts that are a long way down on the bolts, such as on U-bolts.

Each socket has a square hole in its top (Fig. 81) to accept any one of a variety of drive units. The commonly used drive units are illustrated in Fig. 80. The square lug of the drive unit comes in standard sizes of ¼, ⅜, ½, and ¾ inch. The sizes most often used are ⅜ and ½ inch. Heavy-duty 1-inch and 1-½-inch are also made. Most metric sockets are designed to be used with these inch-size square lugs.

The speed handle is used for quickly installing or removing loose nuts that spin freely. However, it does not allow enough twisting force for final tightening.

The most commonly used handle is one that "ratchets". The ratchet handle allows you to pull (Fig. 83), and then back up the handle and pull again — without lifting the socket off the bolt.

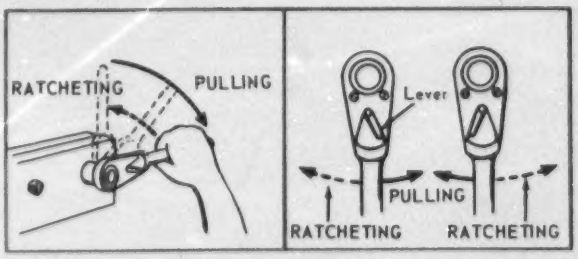

Fig. 83 — Using a Ratchet Handle

The ratchet can be set so it will lock in either direction and ratchet freely in the other.

Other useful drive accessories, such as a universal joint, hinged offset handle, sliding offset handle, are also available.

SPANNER WRENCHES

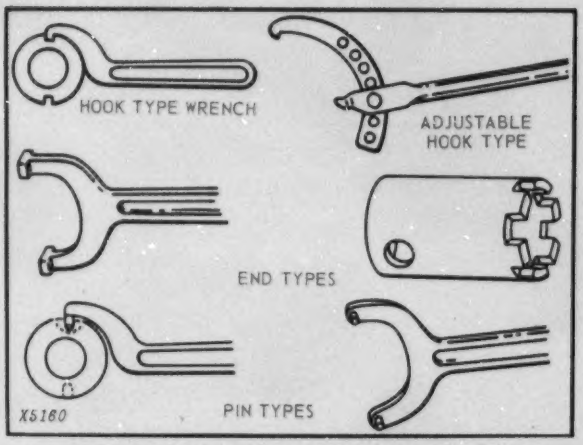

Fig. 84 — Variations of Spanner Wrenches

Sometimes it is advantageous for designers and manufacturers to use fasteners akin to nuts and bolts, but without heads; instead, they have slots or holes around their circumference or on their end. Spanner wrenches are used to remove and install these parts. Several types are shown in Fig. 84. Spanner wrenches are usually classed as "special" tools and are often furnished with a machine that requires their use. However, adjustable hook spanners are available from many tool suppliers.

TUBING WRENCHES

A tubing wrench (Fig. 85) is similar to a box wrench but has a cut-out large enough to slip over pipes and hydraulic tubing and engage the connector. When using one of these wrenches, pull only in the direction of the arrow in Fig. 85 to avoid spreading the wrench opening.

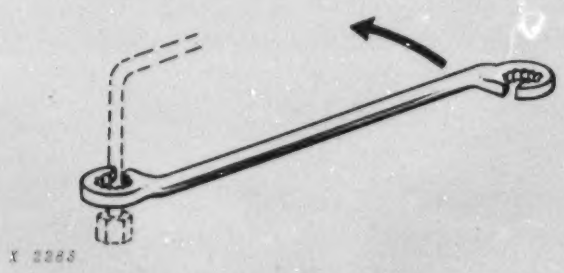

Fig. 85 — Tubing Wrench

TENSION AND TORQUE

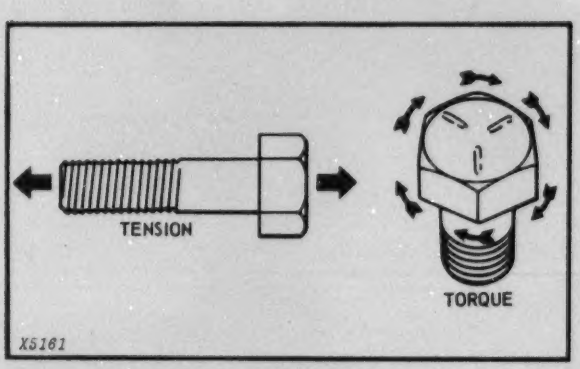

Fig. 86 — Tension and Torque

Among the many fasteners so far devised few are as versatile, reliable and convenient as bolts, nuts and cap screws.

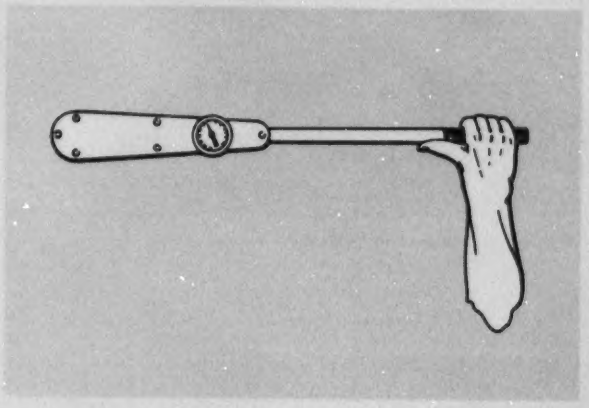

Fig. 87 — Tightening a Bolt the Proper Amount

However, for them to do their job properly in many applications, they must be installed properly and *tightened* just the right amount (Fig. 87). This also applies to other fasteners like machine screws, set screws and studs in certain applications.

An *undertightened* bolt or nut may work loose and come out. In addition, it allows a "shearing" force

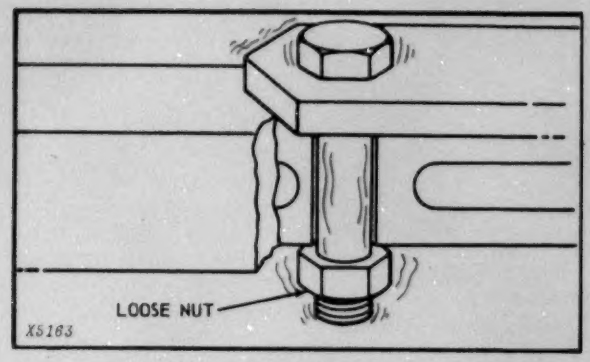

Fig. 88 — A Loose Bolt Allows a "Sheering" Force

to develop (Fig. 88) between the mating parts as they try to move. This shearing may actually cut the bolt in two. Undertightening also causes the bolt to "fatigue" and break as explained a little later.

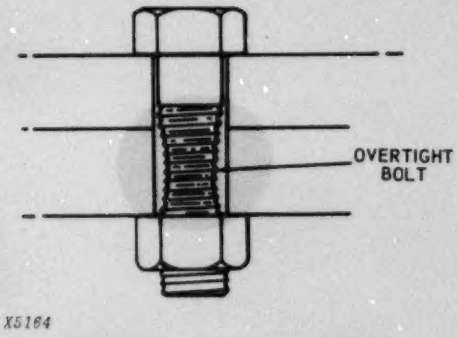

Fig. 89 — An Overtightened Bolt will "Neck out"

The threads of an *overtightened* bolt can be permanently damaged and *"neck out"* (Fig. 89), loosening their grip on fastened parts. If retightened, this bolt will probably break. If a nut is overtightened, it is compressed and the threads contract. The nut actually becomes deformed (Fig. 90); the thread pitch is thrown off and the nut locks in place. Overtightening may also cause assembled parts to become warped or misaligned.

It may surprise you to learn that a sturdy, tough-looking piece of tempered steel like a ⅝-inch SAE grade 5 or 8 bolt will stretch — but it will. In fact, its very usefulness is based on the fact that it will

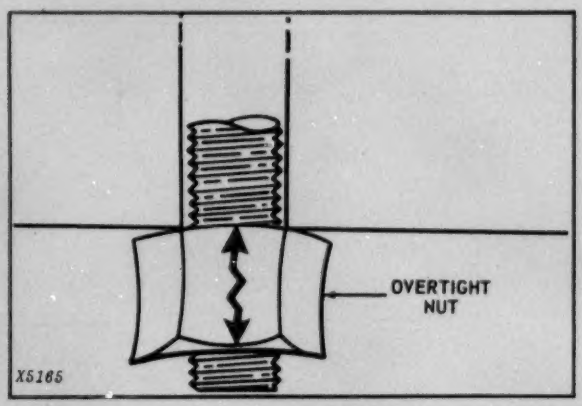

Fig. 90 — An Overtightened Nut will be Deformed

stretch. And here's where *tension* and *torque* enter the picture.

For a bolt to fasten parts together properly, it must be under the correct *tension*; it must be *stretched*. But it must be stretched just the right amount. Here's why.

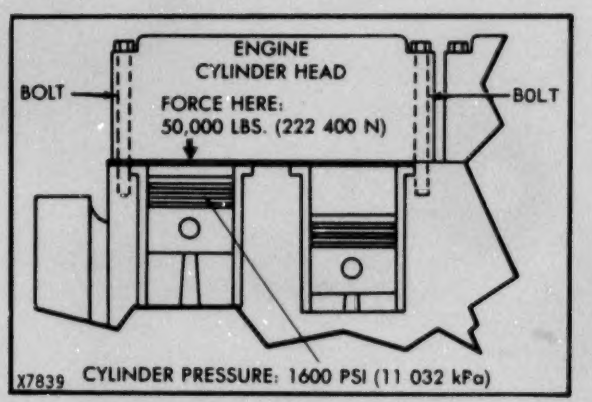

Fig. 91 — Pressure Developed in an Engine

Consider the cylinder head bolts on a tractor engine. Everytime the fuel ignites, the cylinder head is subject to great pressure — often a total force of 50,000 pounds (222 400 N) (Fig. 91) can be pushing up on one side of the head at peak cylinder pressure. If the bolts are not tensioned (stretched) when installed, the pressure *will* cause them to stretch. They will then relax and shrink to normal

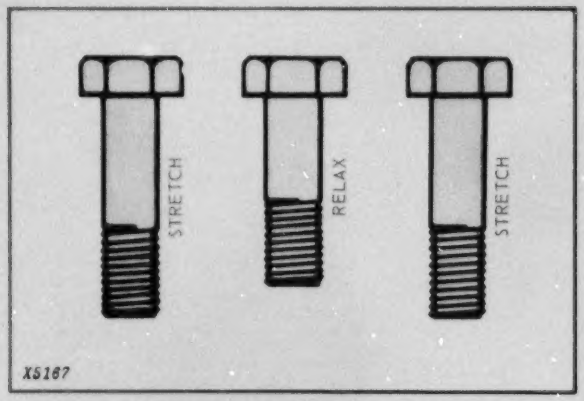

Fig. 92 — The Stretch-Relax Cycle

length when the pressure diminishes (Fig. 92). This constant stretching and relaxing will lead to metal *fatigue* and eventual failure.

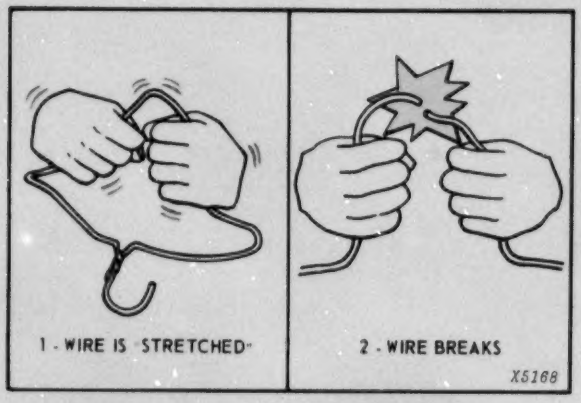

Fig. 93 — A Wire Breaks Under Repeated Stress

Fatigue? Most materials, including steel, "get tired" and fail under *repeated* stress. Take a wire coat hanger (Fig. 93) for instance. Bend it back and forth in the same place several times and the wire will break. The metal has become fatigued. The same holds true of a bolt when it is subjected to constant stretching and relaxing.

But when the bolt is correctly tensioned to stretch it a little, the internal tension is greater than the repeatedly applied external tension; the bolt no longer stretches under stress any more than it is already stretched (Fig. 94). The cause of fatigue is gone and the fatigue life of the bolt becomes infinite.

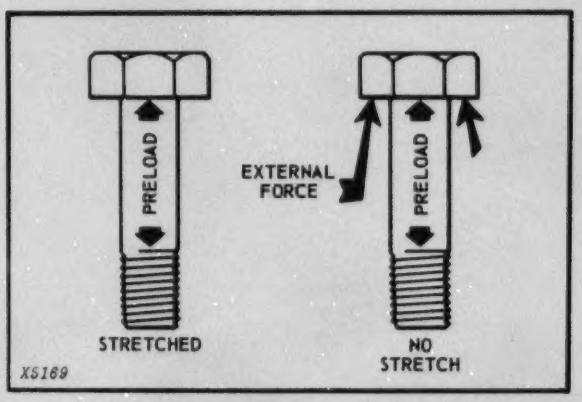

Fig. 94 — Properly Tensioned, Bolts No Longer Stretch Under Stress

Here's a word of caution: Most fasteners must be stretched to do their job, but they *can* be stretched too much.

All metals have what is called their *limit of elasticity*, often shortened to "elastic limit". When a bolt, for instance, is stretched too much (beyond its elastic limit), some of the stretch becomes permanent and the bolt will no longer return to its original length when the tensioning force is removed; it becomes longer than it was originally. This "over-stretching" alters the bolt internally and it is placed in what is called a "plastic" condition.

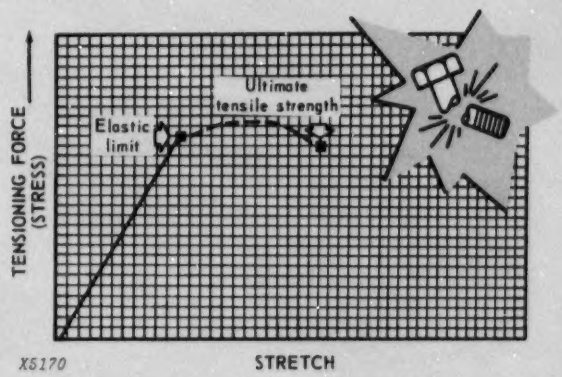

Fig. 95 — How Tensile Strength is Lost When Bolts Are Stretched Too Far

It no longer has its original tensile strength; it is no longer a reliable fastener and is likely to fail quickly. In the graph (Fig. 95), see how the ultimate tensile strength falls off drastically when a bolt is stretched beyond its elastic limit.

How much stretch? Through experience and calculations just the proper amount has been determined for many standard fasteners.

Of course it is impractical to measure stretch directly, so long ago a method was devised to determine stretch in terms of *tension*.

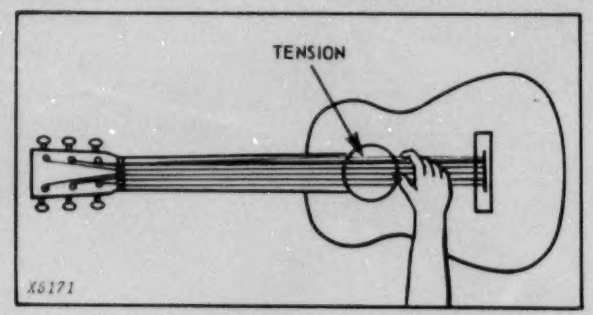

Fig. 96 — Tension Applied to a Guitar String

Tension (Fig. 94) is merely a measure of tautness, or straight pull, measured in pounds. Like stretch it is difficult to measure. So a means has been devised to measure tension in terms of *torque*, as you'll soon see.

TORQUE

Torque is simply a turning effort (Fig. 97). Since "turning" involves a rotary force, torque is "applied effort" or "twist", in a *rotary* direction. It has been learned that when a bolt or other fastener has been "torqued" a certain amount, it will be under the proper tension to do its job.

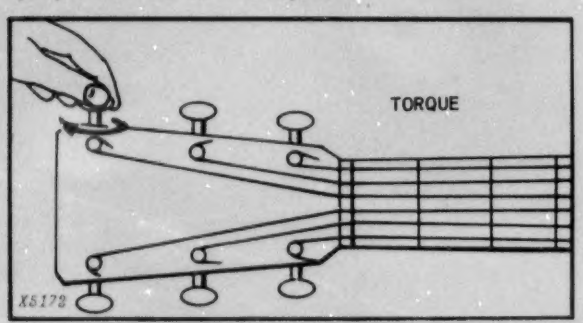

Fig. 97 — Applying Twist or "Torque"

Torque is determined by measuring the amount of *twist*, applied at a given *distance* from the center of the part being twisted. *Twist* is expressed in some common unit of weight like pounds, ounces, grams, or kilograms, while *distance* is expressed in units of length like inches, feet, centimeters, or meters. *Torque* is a product of these two measurements; that is, force times distance = torque. See Fig. 98. This, by the way, is a fundamental law of the lever and is a measure of *work*.

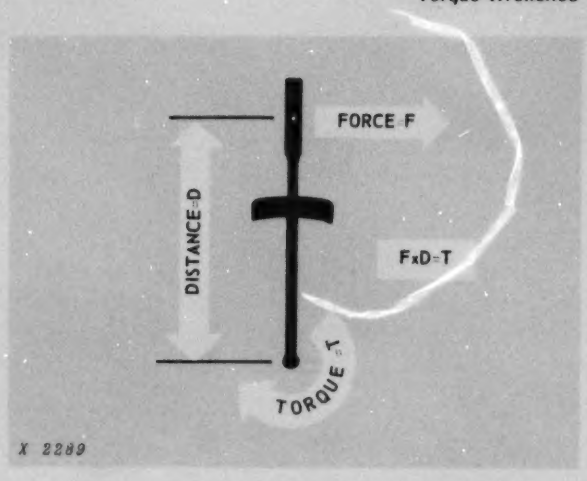

Fig. 98 — How Torque is Measured

Torque is expressed in the names of units used; that is, if force is in pounds and distance in feet, the answer is called pound-feet (lb-ft) or foot-pounds (ft-lbs). It really makes no difference to a serviceman which unit comes first. In the metric system the force factor is usually given first (i.e., Newton-meters), so for consistency pound-feet is probably the preferred order of words. However, in service work the term "foot-pounds" is so widely used in technical and shop manuals, and on torque wrenches, and since it means exactly the same as pound-feet, it is perfectly all right to use.

NOTE: Newton is a measure of force in the metric system. It reflects both weight and acceleration imparted by gravity. Newton = Weight (kg) × 9.81 (factor for gravity).

All this simply means is that torque provides a convenient method of determining "tension" or "stretch".

Engineers have found through experience and calculations just how much torque must be applied to a given fastener to stretch it the proper amount. When properly torqued, a ⅝-inch cylinder head bolt, for instance, will stretch about fifteen thousandths of an inch (0.015") (0.38 mm) (Fig. 99). This is equivalent to the thickness of about 10 pages (5 sheets of paper) in this manual.

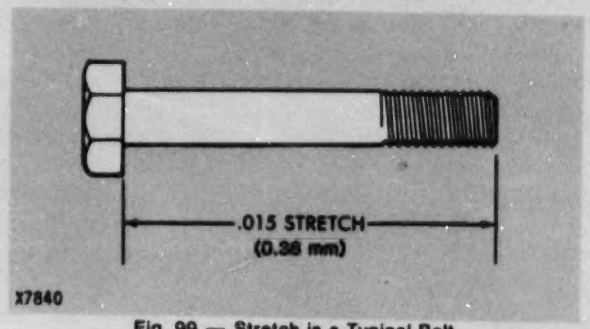

Fig. 99 — Stretch in a Typical Bolt

TORQUE WRENCHES

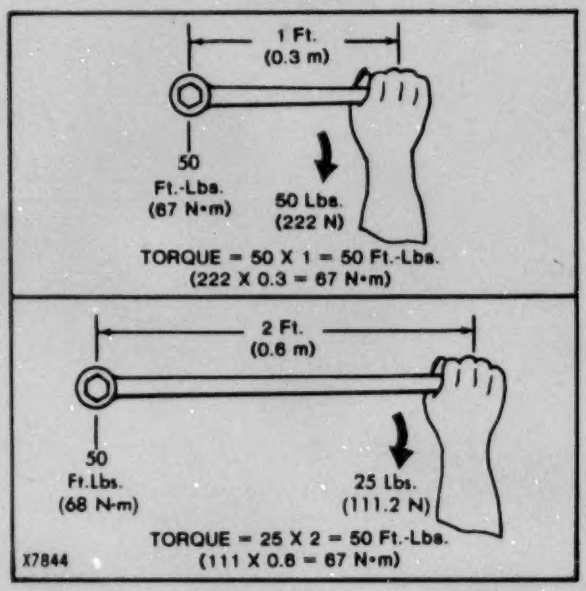

Fig. 100 — Using a Plain Wrench to Determine Torque

You *could* measure torque without anything special. For example, if you wanted 50 foot-pounds, (67 N•m), you could use a wrench 1 foot (0.3 m) long (Fig. 100) and pull on the end of it with a force of 50 pounds (222 N), or — by using a wrench 2 feet long (0.6 m) and applying 25 pounds (111 N).

But there's an easier way. Wrenches have been devised that tell you, when the handle is pulled, how much torque is being applied. These are called *torque wrenches* (Fig. 101). The handle on most torque wrenches is not exactly 1 foot or 2 feet long (0.3 m or 0.6 m), but is designed for ease of use. There are many types of torque wrenches. On some a pointer indicates on a scale or dial when the desired torque has been reached. On others you preset the desired torque and a signalling device tells you, by means of a click, beep or a flashing light, the instant the *preset torque* has been applied.

Lever length is the distance from the center of the drive square (Fig. 101) to the axis of the handle pivot where the force is concentrated.

If the lever length is measured in inches (mm) and the force in pounds (Newtons), then the torque developed is measured in *Inch-Pounds (Newton-Millimeters)*. If the lever length is measured in feet (meters), then the result is in *Foot-Pounds (Newton-Meters)* (Fig. 102). You'll immediately recognize that:

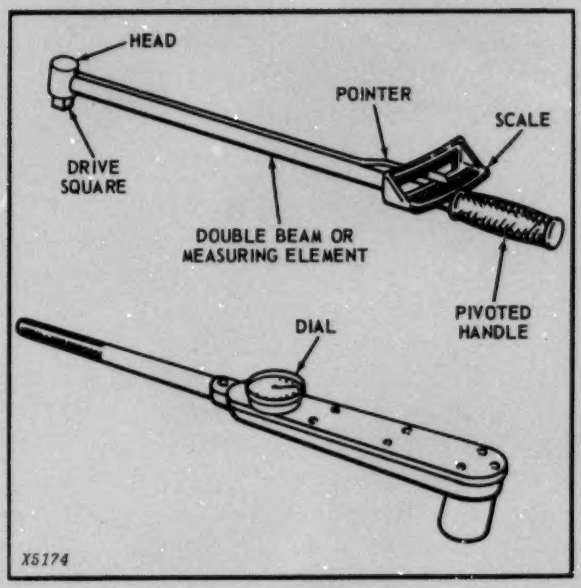

Fig. 101 — Typical Torque Wrenches

Foot-Pounds multiplied by 12 = Inch-Pounds
(Newton-Meters multiplied by 1000
= Newton-Millimeters)
and
Inch-Pounds divided by 12 = Foot-Pounds
(Newton-Millimeters divided by 1000
= Newton-Meters)

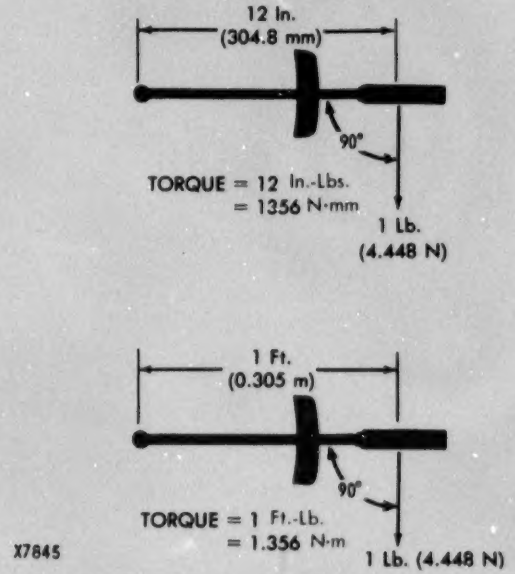

Fig. 102 — Inch-Pounds and Foot-Pounds (Newton-Millimeters and Newton-Meters)

ADAPTER AND EXTENSIONS

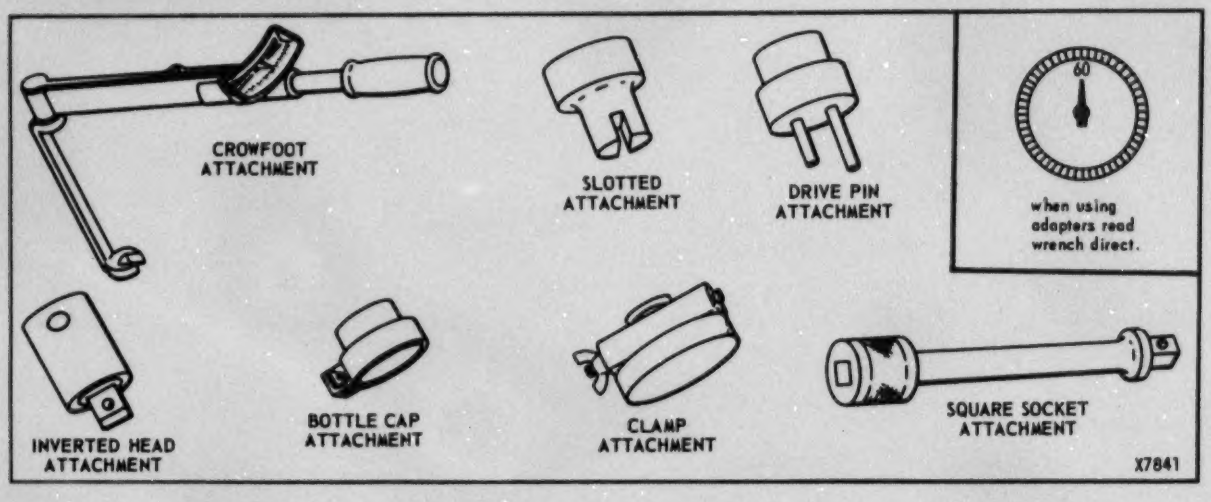

Fig. 103 — Some of the Many Available Adapters

Adapters

There are a number of adapters (Fig. 103) available to help you torque odd-shaped fasteners, or those in hard-to-reach places.

Usually an adapter doesn't increase the effective length of the torque wrench, so the reading on the wrench is the same as it would be without the adapter. However, if the adapter increases the length of the wrench, it must be treated as an extension as discussed next.

Extensions

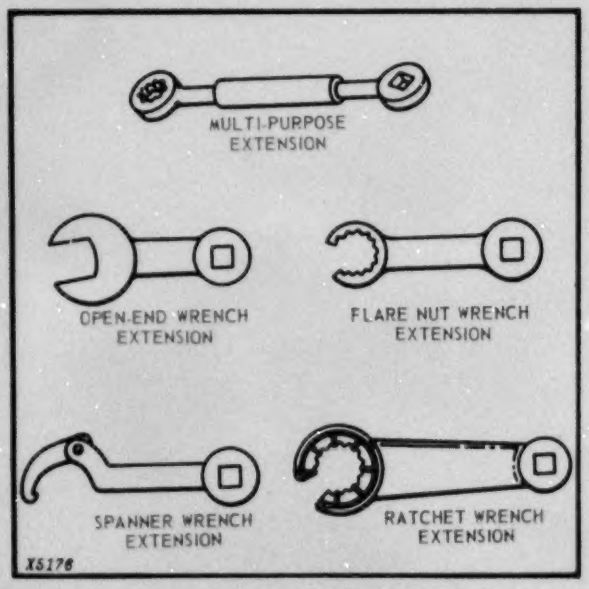

Fig. 104 — Typical Extensions

The maximum pull that the average man can exert on a wrench with safety is about 100 pounds (445 N). So extensions (sometimes adapters are also extensions) are available that increase the length of the torque wrench. Some typical extensions are shown in Fig. 104.

When using an extension you'll recognize that since the length of the wrench is increased, an adjustment in the reading must be made. (Remember force times *length*?)

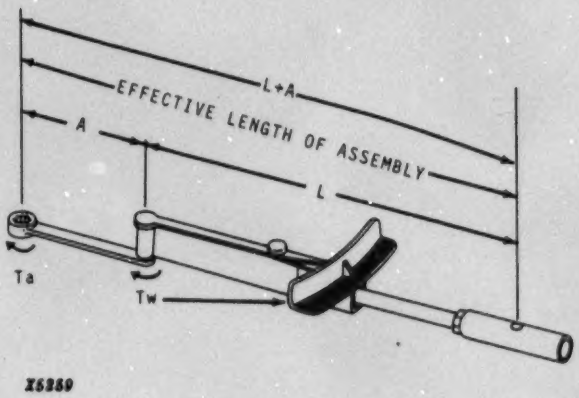

Fig. 105 — Using a Torque Wrench Extension

With an extension the total effective length is the *sum* of the wrench length plus the adapter length as shown in Fig. 105.

In Fig. 105 the letters stand for the following:

L = wrench length
A = extension length
Ta = torque at end of extension
Tw = torque wrench reading

If you want to tighten a bolt to a specified torque, you'll have to know what the wrench will read to give that torque. To do so, use the following formula:

$$Tw = Ta \times \frac{L}{L + A}$$

Example: The shop manual instructs you to tighten a certain bolt to 200 ft-lbs (271 N-m) torque. The torque wrench is 2 feet (0.6 m) long and a 6-inch (½-foot) (0.15 m) extension is used. Applying the formula,

$$Tw = 200 \times \frac{2}{2 + ½} = 160 \text{ ft-lbs}$$

$$Tw = 271 \times \frac{0.6}{0.6 + 0.15} = 217 \text{ N-m}$$

You'd pull on the handle until the dial read 160 (217) which would give you 200 ft-lbs (271 N-m) torque on the bolt.

If, on the other hand, you want to know what torque will be developed on a bolt by a given reading on the wrench, use the following formula:

$$Ta = Tw \times \frac{(L + A)}{L}$$

USING A TORQUE WRENCH

Correct torque is one of the keys to quality workmanship. But, like many jobs, the road to satisfactory results has certain pitfalls and road blocks.

Torque wrenches are not complicated devices, but there are certain techniques that, when followed, will produce good results, and help you around some of the pitfalls and road blocks. Here are a few of them.

1. Pull the wrench with a smooth, even action (Fig. 106). This is very important. Never use short, jerky pulls. The reason is simple: Jerks cause momentum to build up in your arm and body, and by the time you stop applying force, the cap screw or bolt will be over-torqued.

2. Dirt interferes with accurate torque results. It will be impossible to torque properly if parts and tapped holes are dirty. Cleanliness cannot be emphasized too strongly.

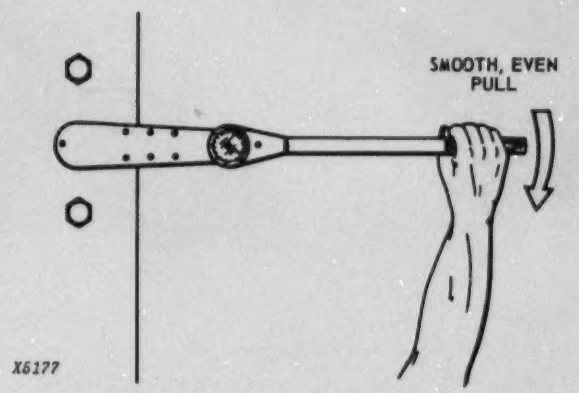

Fig. 106 — Pull Wrench with Smooth, Even Action

3. Remember that friction is ever-present and can be both good and bad. It helps keep parts together, but on the other hand, it may create false results when torquing. Only 10 to 20 percent of a mechanic's effort (Fig. 105) is used in stretching a fastener.

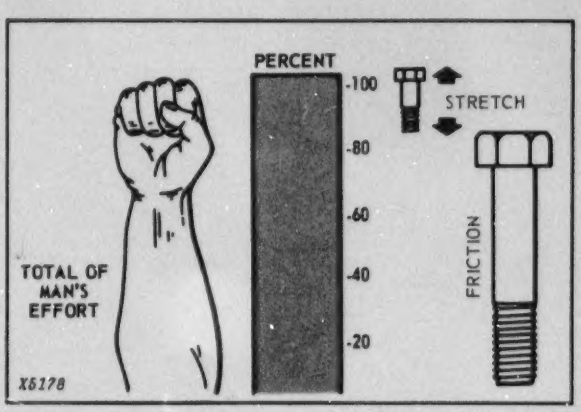

Fig. 107 — How Total Effort is Distributed

In many cases 40 to 50 percent of the torque applied is used to overcome the friction between the

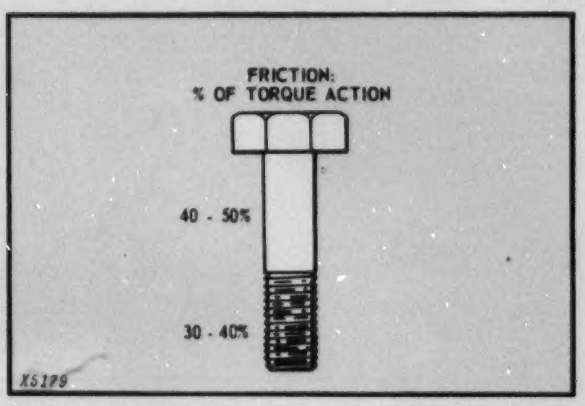

Fig. 108 — Percent of Torque Absorbed by Friction

head of the bolt and the surface being clamped (Fig. 108). Additional friction occurs along the mating threads of the bolt and the tapped hole. So bear in mind all these factors of friction plus those which follow when torquing.

4. When tightening a nut or bolt with damaged or blocked threads, note what torque is required to move through the damaged area. Then add this extra torque to the recommended reading.

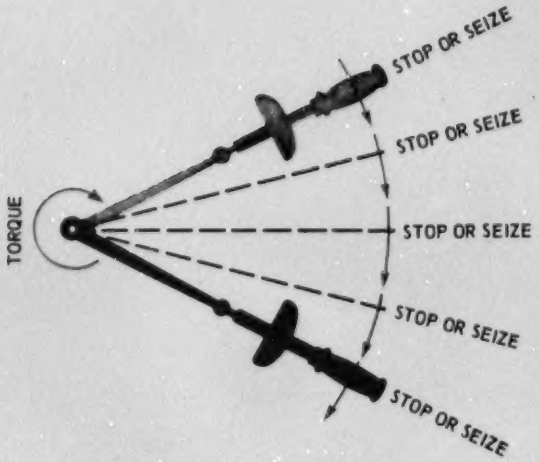

Fig. 109 — How Seizure Occurs

5. Sometimes a *set* or *seizure* will occur while tightening a fastener (Fig. 107). This is indicated by a popping effect during the final stages of tightening. When a seizure occurs, back off the bolt or nut and retighten it with a steady sweep of the wrench handle. Take the torque reading while the wrench is moving.

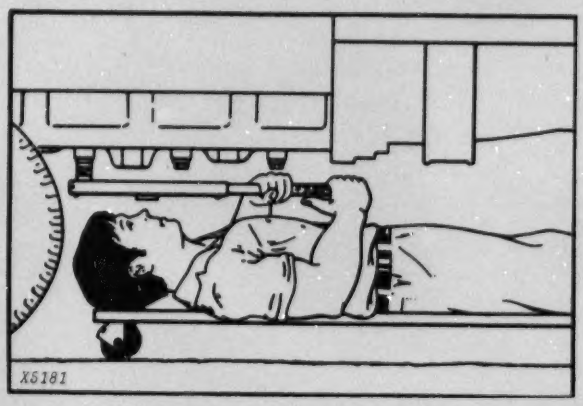

Fig. 110 — Working in Close Quarters

6. Limited space often hinders the torquing process (Fig. 110). In some areas it is difficult, if not impossible, to get enough leverage and read the scale at the same time. Ask a fellow worker to come over and give you a hand under these circumstances.

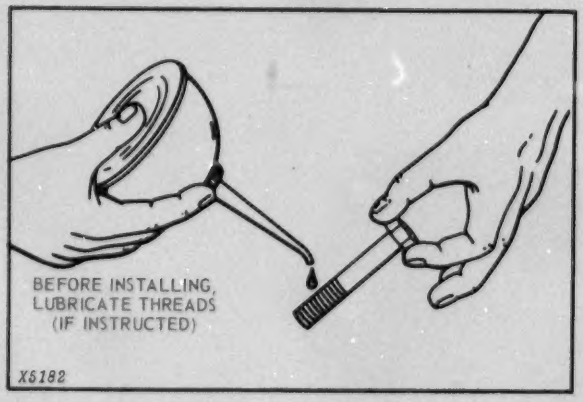

Fig. 111 — Lubricating the Threads of a Cap Screw

7. Lubricate bolts or cap screws (Fig. 111) if the manufacturer so instructs. If oil is used, be careful not to apply too much. Excess liquid may accumulate in the bottom of a drilled hole in a casting. If the bottom of the screw presses on the liquid,

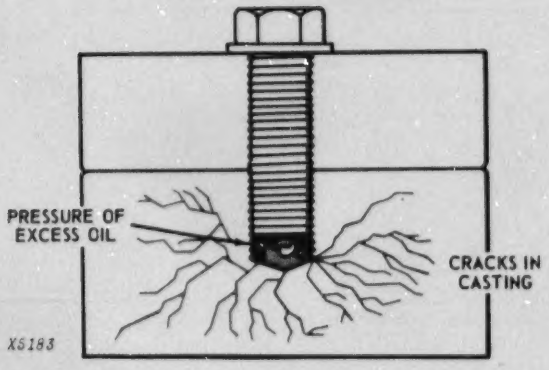

Fig. 112 — Too Much Oil May Create a Hydraulic Lock

a "hydraulic lock" is created which may burst the casting (Fig. 112).

8. *Practice Makes Perfect.* A basketball coach can teach his team the fundamentals of basketball but the players become great only after hours of practice. The same is true of a torque wrench. Only after using it many times, and getting the feel of it, will you become proficient in its use.

9. The chart on pages 68 and 69 gives torque values for some of the most common fasteners. These values are based on the fastener's diameter, length, the material from which it is made, and the treatment it may have received when manufactured. However, many manufacturers have worked out torques for their specific applications that may differ from those in the chart. These are usually published in technical manuals or other publications. **Always** use these figures, when available, instead of those in the chart.

10. Quite often, as in the case of cylinder head cap screws, tightening sequence is important. Again, follow the manufacturer's instructions.

The above are just a few helpful hints that, if followed, will ease your job. There is an additional wealth of material written about torque and torque wrenches. See, for instance:

John Deere "Fundamentals of Service, Shop Tools". Also check your local library, tool supplier, and the publications of engine manufacturers.

MAINTAIN ACCURATE WRENCHES

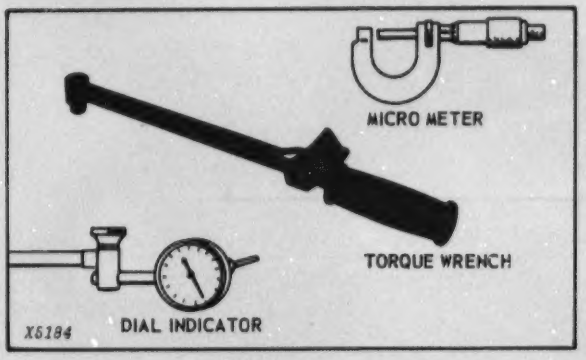

Fig. 113 — A Torque Wrench is a Precision Instrument

Here's something important to remember. A torque wrench is a precision instrument. Handle it carefully just like you would a micrometer or dial indicator (Fig. 113). The tension in a fastener can be no more accurate than the accuracy of the torque wrench. If it is dropped or otherwise damaged, check it, or have it checked for accuracy. It's best to have it checked on a special wrench tester (Fig. 114) if one is available close by; or, if time permits, return it to the manufacturer who will check, and if necessary, repair and adjust it for you.

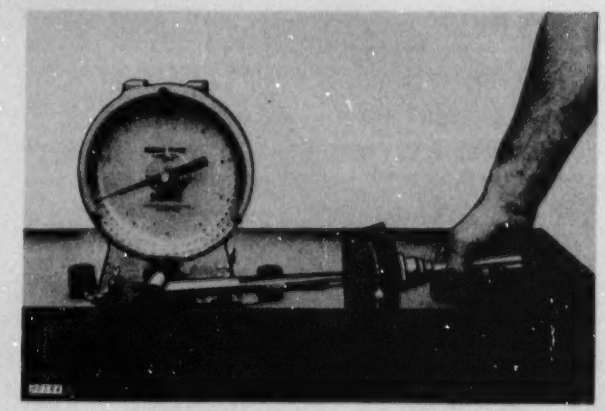

Fig. 114 — Testing a Torque Wrench

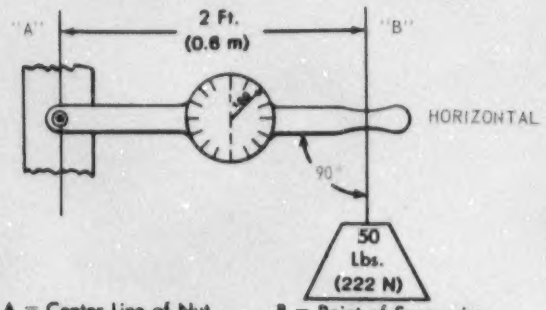

Fig. 115 — Testing a Torque Wrench without Using Special Tools

In an emergency you can check the accuracy of a torque wrench yourself as follows:

1. Hang the torque wrench on a fixed nut as shown in Fig. 115.

2. Set the indicator to "0". (This will compensate for the weight of the wrench.)

3. Hang a known weight from the wrench handle at any known distance from the center of the nut as shown.

4. Weight in pounds multiplied by the distance from A to B in feet will give you foot-pounds of torque. This figure should agree with the indicator reading.

In the example, 50 lbs. x 2 ft. = 100 ft-lbs.
(22.7 kg x 9.81 = 222 N x 0.6 m = 133 N-m).

Remember that any force or distance can be substituted in the formula, "Force x Distance = Torque".

NOTE: To check the accuracy of a flexible torque wrench, hang the weight from the pivot point of the handle. Force x Distance will then give you the torque.

Always check wrenches within the torque range in which they are normally used.

TEST YOURSELF

QUESTIONS

1. Why are the heads of open-end wrenches normally made with an offset?
2. True or false? Some wrenches are called "box" wrenches because they are used to open boxes.
3. Do bolts and cap screws stretch when properly tightened?
4. State the difference between tension and torque.
5. What is a bolt's "limit of elasticity"?
6. Torque is the product of what two types of measurements?
7. Match the three pairs of items below:

   1. Torque a. Straight pull (1) Foot-pounds
   2. Tension b. Turning force (2) Pounds

8. If a shop manual calls for 50 foot-pounds, how much is that in inch-pounds?

(Answers on page 71.)

We've strayed from the subject of fasteners so we could discuss in some detail the tools that are so important to the proper handling of bolts, cap screws, and nuts.

But the story is far from complete. There are other fasteners of great importance that make possible the many things we use in modern-day life. We'll take a look at some of these in the pages that follow.

SCREWS, KEYS, STUDS, PINS, SNAP RINGS, RIVETS, AND CLAMPS/PART 4

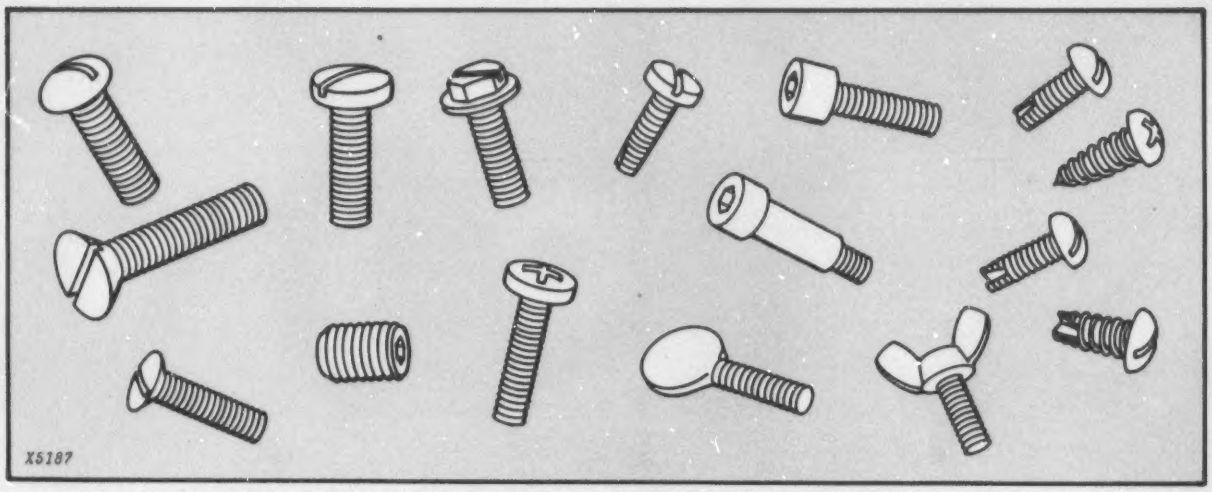

Fig. 116 — There Are Screws of Many Shapes and Sizes for Many Purposes. A Few Representative Ones Are Illustrated Here.

SCREWS

Screws constitute a large and important family of fasteners. They come in many and varied styles and sizes (Fig. 116). Only those you are most likely to encounter will be discussed here.

All screws are threaded lengths of steel rod with a head on one end. There are a large number of head styles. One of the most commonly used is the "Machine Screw".

MACHINE SCREWS

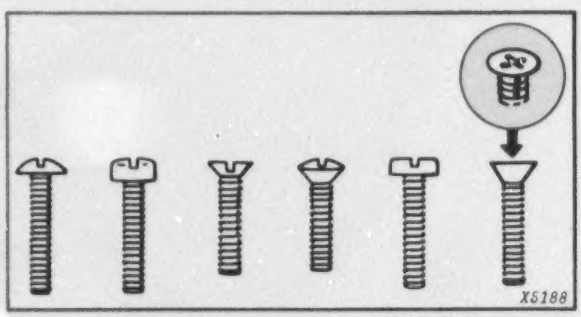

Fig. 117 — Typical Machine Screws

Typical examples of machine screws are shown in Fig. 117. In most applications machine screws are turned into threaded holes, although they may be used with nuts.

At one time or another most everyone concerned with mechanical things has bought machine screws at his local hardware store or other source. When you do so, if the diameter of the screw is less than ¼-inch, you'll notice that the package or box identifies the size of the screws it contains by a small number and a figure in inches. For example, No. 4 X 1½". In the example the No. 4 refers to the diameter of the screw, and the 1½" to its length.

Have you ever wondered just what size, in familiar measurements, the numbers stand for? The chart below tells you.

MACHINE SCREW SIZES

Screw Number*	Size in Decimals	Approximate Size in Fractions
No. 2	0.086"	a little over 5/64"
No. 3	0.099"	a little over 3/32"
No. 4	0.112"	a little over 7/64"
No. 5	0.125"	exactly 1/8"
No. 6	0.138"	a little under 9/64"
No. 8	0.164"	a little over 5/32"
No. 10	0.190"	a little over 3/16"
No. 12	0.216"	a little under 7/32"

**These numbers apply also to lock washers.*

The diameter of screws ¼ inch and larger is expressed in fractions of an inch. These screws are usually made of SAE grade 60M (equivalent to SAE Grade 1) hardware. (See page 9.)

Metric machine screws are identified by the nominal diameter in millimeters (such as M3.5 or M4). The designation may appear as M4 x 0.8 with 0.8 being the distance between threads (pitch) in millimeters. Metric machine screws are usually of the property class 4.8.

FOS — 60 Litho in U.S.A.

Inch-size machine screw threads are counted by the number to the inch, just like bolt threads. A 6-32 screw has a No. 6 body diameter and 32 threads per inch. Most machine screws are fully threaded.

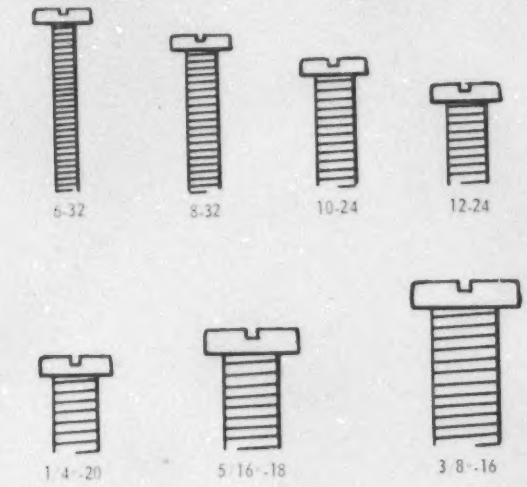

Fig. 118 — Inch-size Machine Screw Sizes and Threads Per Inch — Actual Size

Fig. 118 shows common body sizes and thread count, actual size.

Another widely used machine screw is the *flat head** which also requires a countersunk hole.

The *fillister head* is cylindrical and has a round top. A similar screw design with a flat top that blends into the sides is called a large *pan head* screw.

All of the above screws are installed or removed with a screwdriver. There are a number of sizes and shapes of screwdrivers. A few of these are illustrated in Fig. 120.

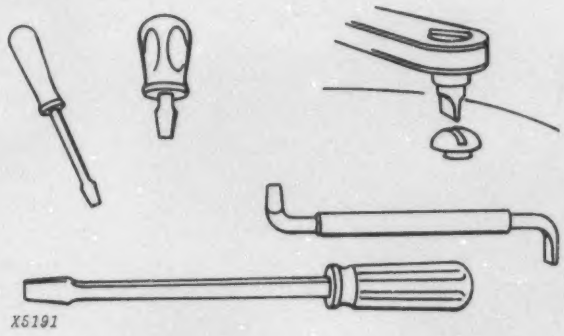

Fig. 120 — Commonly Used Screwdrivers

NOTE: Though screwdrivers are simple tools, they may need reconditioning occasionally. There is a right way and a wrong way to do this. For instructions, see "Fundamentals of Service, Shop Tools".

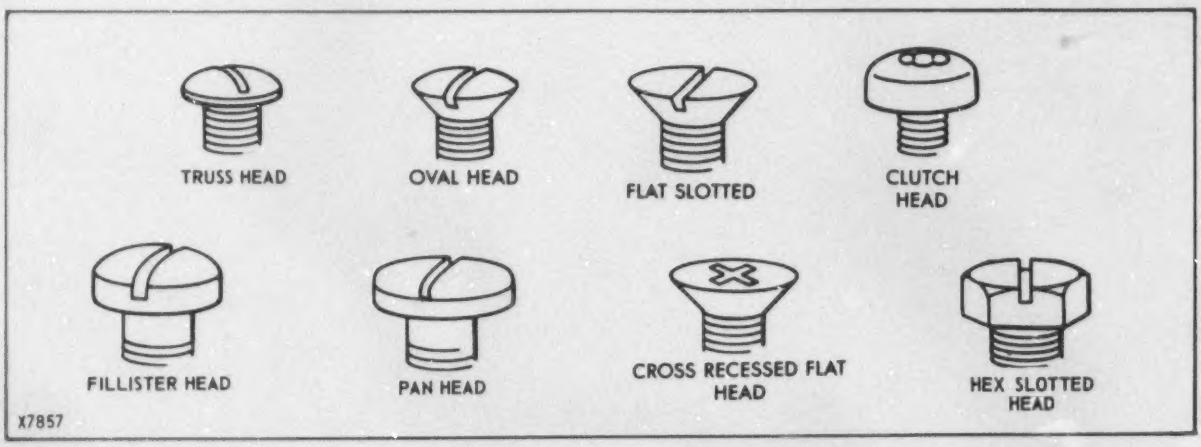

Fig. 119 — Machine Screw Head Deisgns

There are many head designs for machine screws. Those most commonly used are shown in Fig. 119.

The *pan head** machine screw is the most commonly used. Variations of this design are *truss head*, which is wider and rounded, and *oval head* which requires a countersunk hole.

*Stove bolts are identical to round head and flat head machine screws.

When a screw must be installed in close quarters or other places difficult to reach by hand, a starting screwdriver can be used. One type is shown in Fig. 121, next page.

Other starting screwdrivers have twisting centers or are magnetized to hold the screws.

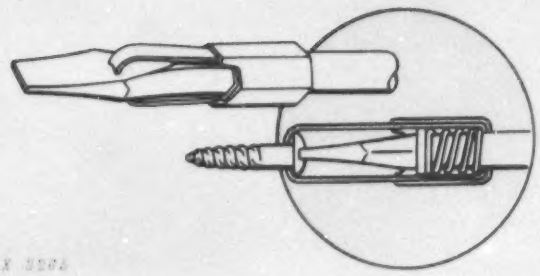

Fig. 121 — Starting Screwdriver (Shown Holding a Screw)

Another variation of machine screw has a cross-recessed head. Two types of cross-recessed heads are shown in Fig. 122. Most metric cross-recessed screws will be of the type on the right. The screwdriver for these has a cross-shaped, pointed tip (Fig. 123). Because of the extra bearing surface between screw and screwdriver, turning force can be quite high, but more force must be exerted to keep the screwdriver point in the slots. Various sizes of cross-shaped, pointed tip screwdrivers are made to fit different screw sizes.

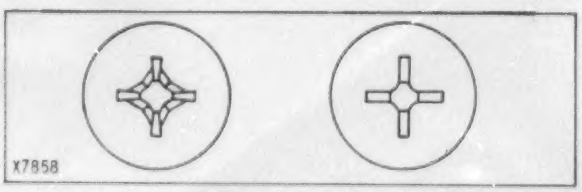

Fig. 122 — Cross-recessed Head Designs

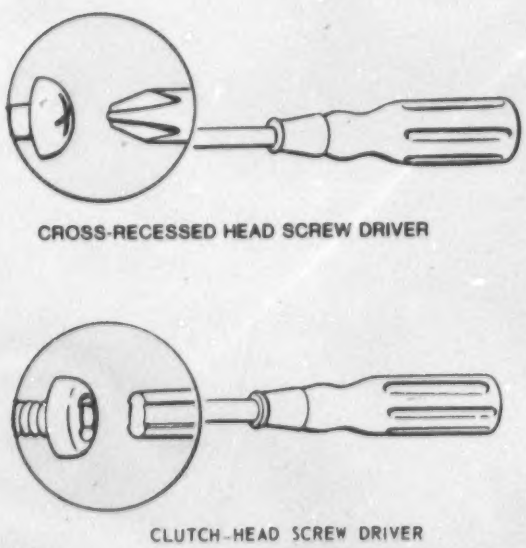

Fig. 123 — Phillips-Head and Clutch-Head Screwdrivers

Screws with hex slotted heads (Fig. 120) are a popular variation of machine screws. These can be installed or removed by means of a screwdriver, a wrench, or a handy, readily available tool with a hex socket, called a nut driver. A nut driver must be procured for each screw size.

When a neat appearance is vital *clutch-head* screws (Fig. 120) may be used to fasten sheet metal and trim. A special screwdriver (Fig. 123) is used to install these screws. The tip stays well in the screw opening and requires only moderate pressure.

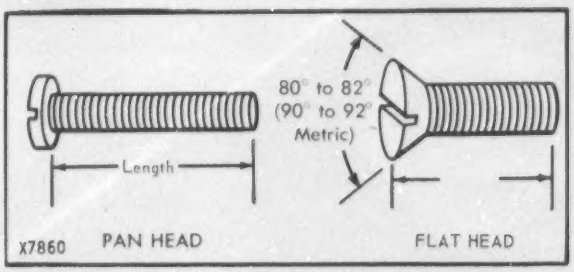

Fig. 124 — Where the Length of Machine Screws is Measured

The length of most machine screws is measured from just under the head to the end of the thread (Fig. 124). However, in the case of flat or oval head countersunk screws, the overall length is measured.

TAPPING SCREWS

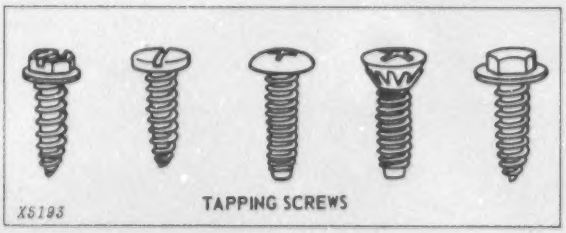

Fig. 125 — Typical Tapping Screws

Another family of screws has been used widely in recent years to attach covers, panels and other light parts. Such parts may be made of sheet metal, soft metal castings (like aluminum, bronze, brass), plywood, fiber glass, plastics, etc. The members of this family are called *tapping* screws (Fig. 125). Another name for them is *thread-forming* screws because they form their own threads in the parts that they are screwed into. A third popular name is *sheet metal* screws.

Most of these screws come with cross-recessed heads in pan, flat, or hex design There are others with special heads or threads that carry a variety of trade names or numbers. They are too numerous to be listed in detail.

The mating threads produced by a tapping screw closely fit the threads on the screw. This close fit usually keeps the screw tight, even under vibrating conditions.

Tapping screw diameters are designated by numbers similar to those used to identify machine screws (page 35). They come with coarse or fine threads and are almost always case hardened to cut satisfactory threads and stand hard twisting force.

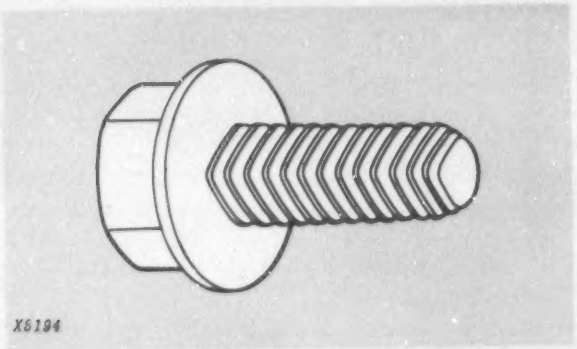

Fig. 126 — A High Performance, Thread Rolling Screw

Fig. 126 shows a "high-performance" thread rolling screw for use in heavier materials that require deep thread engagement. This screw has a three- or four-lobed cross-section to provide three or four thread-forming edges. Body size corresponds to that used for machine screws.

When using most tapping screws, holes of the proper size must be drilled in the parts being fastened.

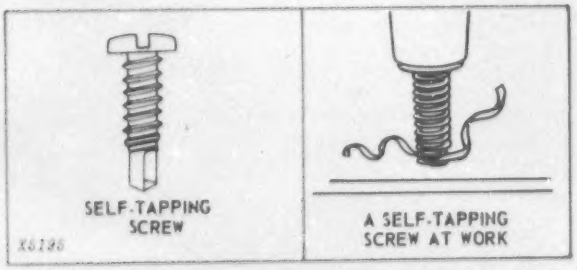

Fig. 127 — Self-Drilling Tapping Screws

Self-Drilling Tapping Screws. An interesting variation of tapping screws is one that has a special point to *drill* its own hole, thus eliminating drilling or punching (Fig. 127). Since these screws must usually be installed with a power tool, you may not encounter them very often.

Fig. 128 — A Typical Drive Screw.

Drive Screws.

Another variation is the *metallic drive* screw (Fig. 128) that is hammered or pressed into the hole for fast installation. These screws have no slots in the head and, once installed, cannot be removed.

SET SCREWS

A set screw is frequently used to hold a collar, pulley, gear or the like to a rotating shaft to prevent relative movement between the two parts. They achieve this by pressing against a flat or by fitting into a small hole in the shaft.

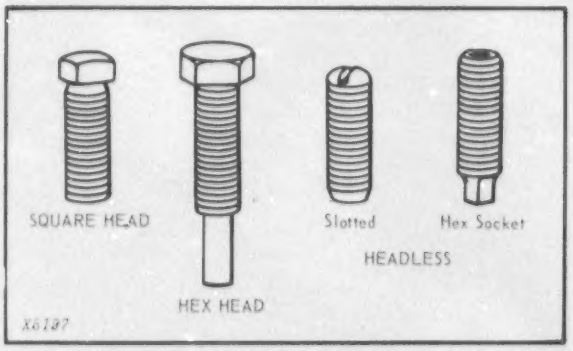

Fig. 129 — Types of Heads on Commonly Used Set Screws

Set screws may have square or hexagon heads (Fig. 129) or may be headless with a screwdriver slot or hex Allen wrench socket.

There are a variety of point styles, each best suited for its job. The more common ones are illustrated

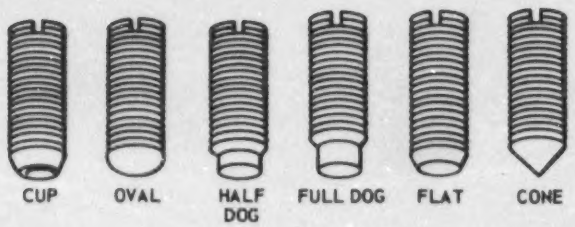

Fig. 130 — Set Screw Point Syles

in Fig. 130. The cup point and dog point are by far the most commonly used.

The cup point screw has applications where the installation is more or less permanent and cutting action of the point on the shaft is not objectionable. Dog point screws are used for the same purpose, but their holding power is more permanent because the point projects into a drilled hole in the shaft.

Set screws with flat or oval points are used when frequent adjustments must be made between the two parts held together.

Set screws are made of high-strength material and are heat treated. Threads may be either coarse or fine. Diameters are expressed by numbers or inch fractions (or millimeters for metric screws), the same as machine screws (page 37).

While set screws have many applications, they are not an especially strong type of fastening because they depend upon friction and a slight amount of "shear" to hold parts together. Furthermore, the cup or cone types usually raise a burr on the shaft which makes the part held to it difficult to remove.

KEYS

One very common way of holding a gear, pulley or other part to a shaft is by means of a *key* (Fig. 131). In some ways the name is misleading because these fasteners do not look like keys in the usual sense. Most are simple lengths of steel cut from square or rectangular stock, or round stock cut in half.

The gear or other part, and the shaft have a groove cut into them. These grooves are called *keyways*.

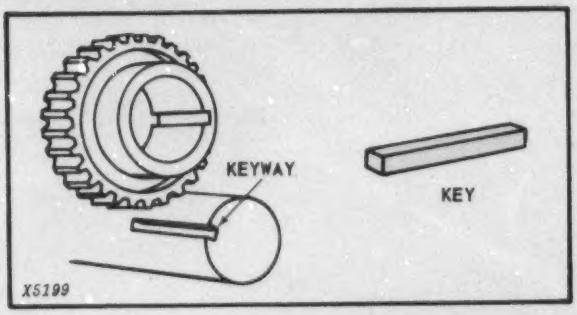

Fig. 131 — A Key and the Keyways in a Gear and Shaft

The square or rectangular key is driven into the keyway when both grooves are matched (Fig. 132). When driving a key in place care must be taken to avoid "upsetting" the end of the key (that is, causing a bulge.) It's always best to drive keys in place with a "soft" or plastic hammer.

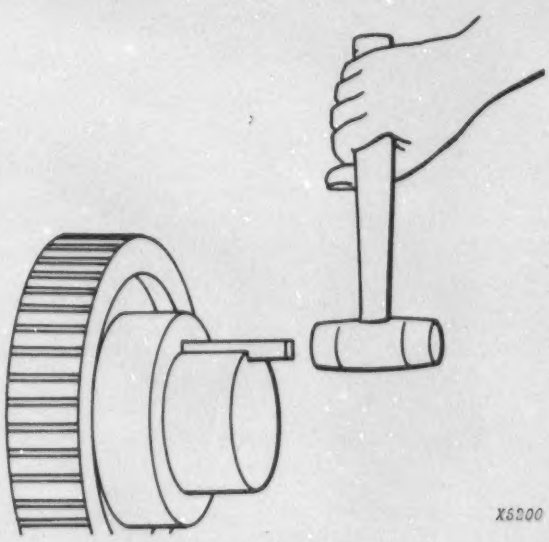

Fig. 132 — Installing a Key

Woodruff Keys. (See illustrations, next page.) A semicircular key made from round stock cut in half (like a half moon) is called a *Woodruff* key. This key is used to lock the shaft and gear in one position, rather than simply to anchor the gear onto the shaft.

Another reason for using a Woodruff key is added strength. In some applications a straight, square key has a tendency to "rock" because it cannot be sunk deeply enough into the shaft. In such a case a Woodruff key is used because its keyway is much deeper than an ordinary keyway, and doesn't extend along the shaft to weaken it.

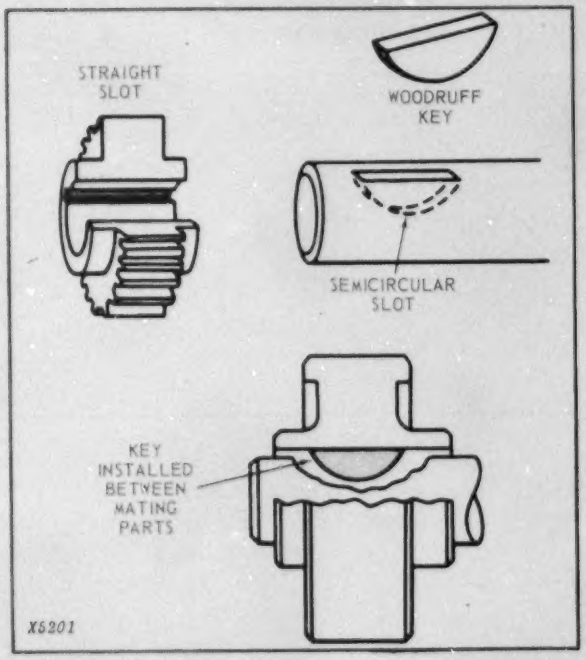

Fig. 133 — How a Woodruff Key is Used

When a Woodruff key is to be used, a semicircular keyway (Fig. 133) is cut in the shaft.

The gear to be mated to the shaft has a straight slot cut through it.

The Woodruff key is placed in the curved slot in the shaft and projects above the shaft far enough to fill the slot in the gear. The gear is then driven or pressed onto the shaft.

Woodruff keys have two dimensions — diameter (or length) and thickness — and come in many sizes. Metric Woodruff keys are designated by width and height.

Installing and removing key-held parts such as gears requires special care, and often special tools, since these parts usually fit on their shafts very tightly. When performing these operations always follow the instructions of the manufacturer of the machine. Using hammers, pry bars and chains to remove a stubborn gear or other part may only cause more problems. Special pullers (Fig. 134) which fit the parts and apply force evenly and smoothly are often the answer.

There are many different types of mechanical and hydraulic pullers. For more about puller and how to use them, see "Fundamentals of Service, Shop Tools."

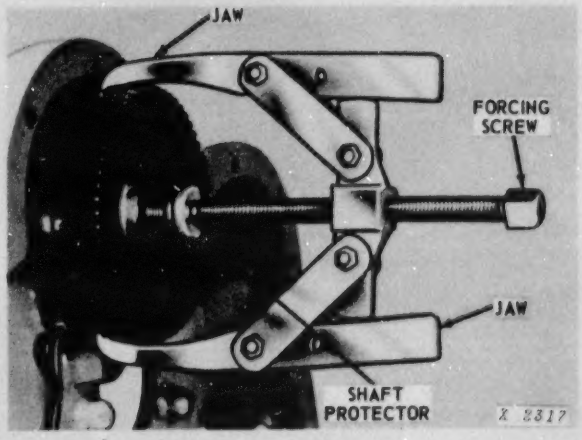

Fig. 134 — A Typical Gear Puller

To install some gears and other parts, it is necessary to heat them to a high temperature in an oil bath. The heat causes the gear or part to expand, increasing the size of the bore so the gear or part will slide more easily on the shaft.

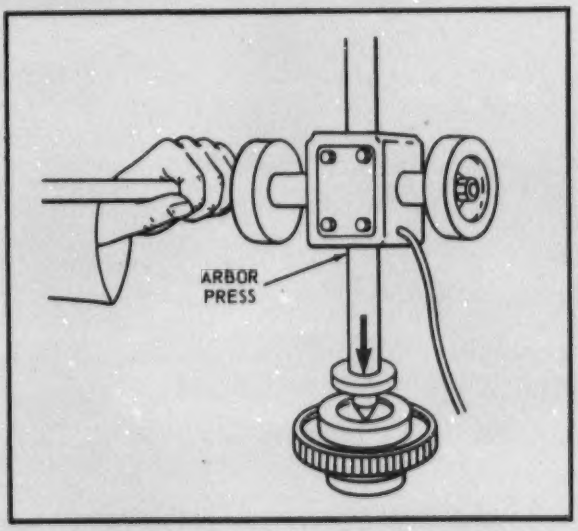

Fig. 135 — Using a Arbor Press to Remove a Gear

Some gears or other parts are *press fits* which require the use of an arbor press (Fig. 135). Again, follow the manufacturer's instructions.

STUDS

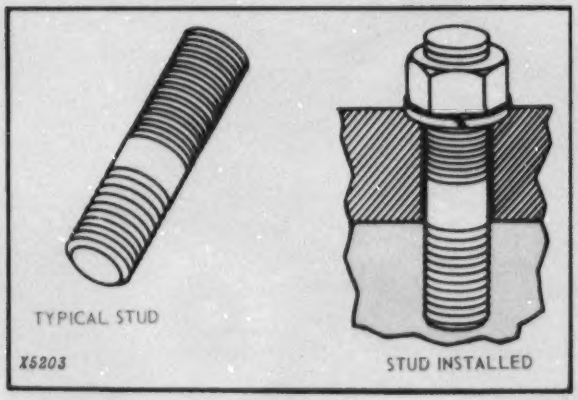

Fig. 136 — A Typical Stud

Another type of fastener is the stud (Fig. 136) which is merely a steel rod with threads on both ends.

One end is screwed into a part, other parts are assembled over the studs and screwed in place with a nut. Sometimes a lock washer is also used.

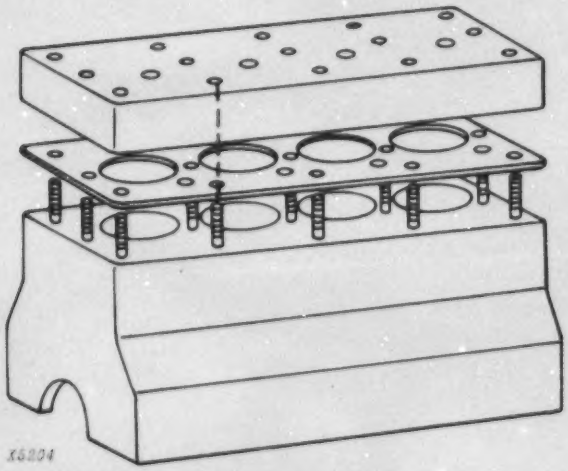

Fig. 137 — How Studs Simplify the Assembly of Several Parts

The advantages of studs over bolts and nuts or cap screws is primarily in manufacturing processes. During assembly of an engine, for instance, they act as *pilots*. You can see how much easier it is to slip a gasket and cylinder head onto studs screwed into the cylinder block (Fig. 137) rather than to line up many holes through the head and gasket for cap screws.

Most studs have coarse threads on one end and fine threads on the other. One type has coarse interference threads on the "tap" end that are larger than the threads in the tapped hole. When the stud is screwed into place the stud threads compress, creating a locking action.

Most studs should not be installed so far that they "bottom" in the tapped hole. To do so may cause the stud to fail, may damage the threads in the tapped hole, or if oil is used, develop a hydraulic lock (page 35).

TAPER-LOCK STUDS

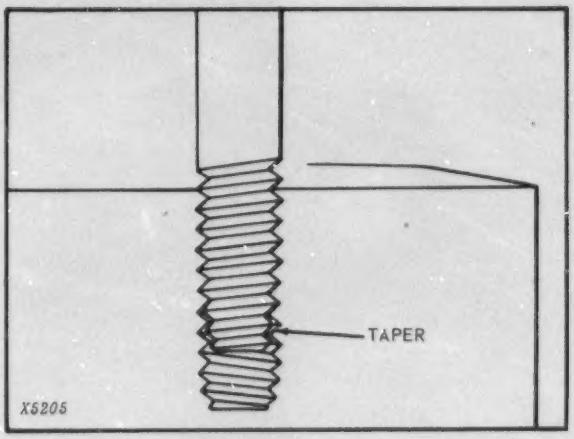

Fig. 138 — A Taper Lock Stud

Another type of stud is called the *taper-lock* (Fig. 138). The tap end is tapered and the mating hole is tapered in the same manner.

A taper-lock stud screws in easily and, unlike other studs, hits the bottom of the hole where the taper or *chamfer* wedges it tightly in place.

Taper lock studs can be unscrewed quite readily and may require tightening or sealing with a sealant if they loosen.

SCHWEPPE STUDS

Fig. 139 — Example of a "Schweppe" stud

Another interesting stud is called the "Schweppe" stud (Fig. 139) which, like some tapping screws,

cuts its own threads. The tapping end is tapered and has double, thread-cutting slots milled in from opposite sides. When this stud is installed, an interference fit develops to hold the stud firmly in place. The Schweppe's use is generally limited to soft, ductile materials like aluminum, magnesium and plastics.

• • • • •

The nut end of a stud has coarse or fine threads (usually fine) to accept a regular nut. Most standard metric studs have coarse threads on both ends. Some are drilled for a cotter pin.

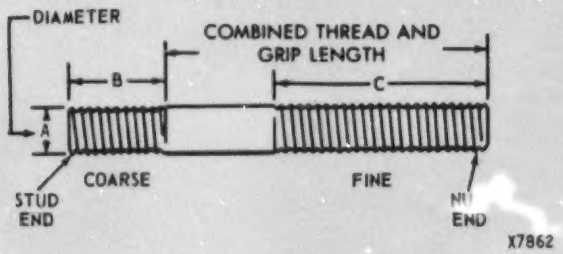

Fig. 140 — How Studs Are Identified

Studs are identified by diameter (A, Fig. 140), the type of thread at each end, thread length at both ends, (B and C), combined thread and grip length of the nut end, and drilled hole, if needed.

As with other fasteners, there are many variations of studs, too numerous to deacribed in detail. Some have interference devices, other than oversize threads, or may have plastic coatings, nylon plugs and epoxy adhesives to keep them tight. Other designs include the use of springs or spring washers in the bottom of the tapped hole to engage the point of the stud.

REMOVING AND INSTALLING STUDS

Studs must be removed or installed with special tools to prevent damage to the body or threads. One special tool, called a "stud driver", has a *housing* (Fig. 141) that fits over a threaded *collet* and can be turned by a socket wrench. The collet has threaded expandable jaws that fit over the nut end of the stud.

A collet that matches the threads on the nut end of the stud is selected. The collet and housing are assembled and screwed onto the nut end of the stud. A socket wrench is then used to turn the tool to install or remove the stud.

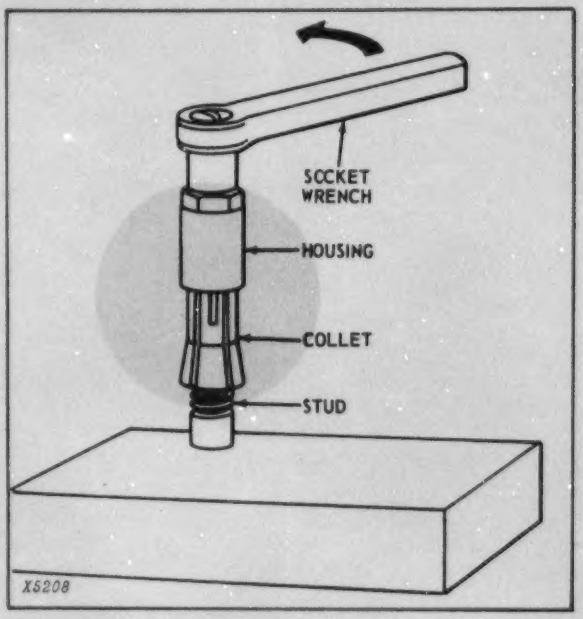

Fig. 141 — Installing or Removing a Stud

If no threads are left on top of the stud body for a stud driver to grip, a cam or wedge-type *stud puller* (Fig. 142) can be used. The puller automatically grips the stud with a knurled cam or wedges as turning pressure is applied with a socket wrench drive handle and the stud will come out.

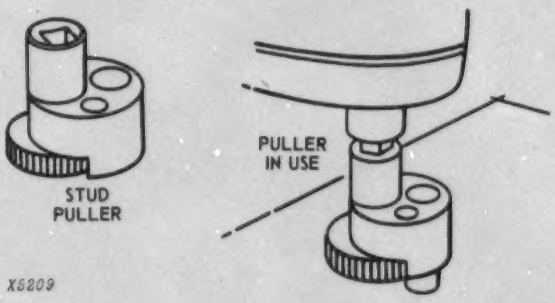

Fig. 142 — Cam-Type Stud Puller

The need for removing a stud is usually because it is broken off at or below the surface. To remove these studs, extractors of various types are available.

The most common extractor, which has become known as an "Ezy-Out" is a hardened, tapered rod with coarse, sharp, left-handed spirals, resembling threads (Fig. 143). A "flat" on top is provided so the tool can be turned with a wrench.

To use the extractor a hole is drilled in the exact center of the stud. This must be done carefully; most studs are hard and difficult to drill. Extractor kits are available with guides (Fig. 143) that center the drill in the hole and keep it straight.

The extractor is inserted into the hole where it securely bites into the stud and allows it to be unscrewed.

Extractor sets contain extractors in several sizes, guides in several sizes to center the drill, and other useful items.

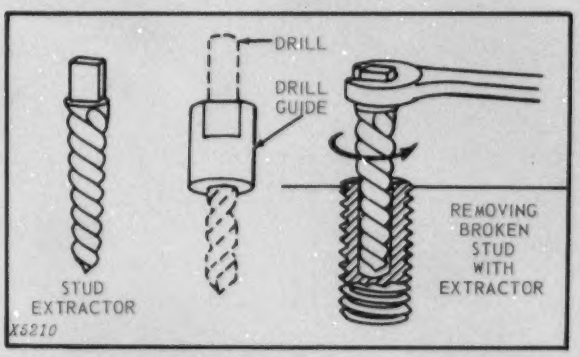

Fig. 143 — Extractor for Removing Broken Studs

NOTE: Although these tools are commonly called stud removers, they can also be used to remove broken bolts and cap screws.

PINS

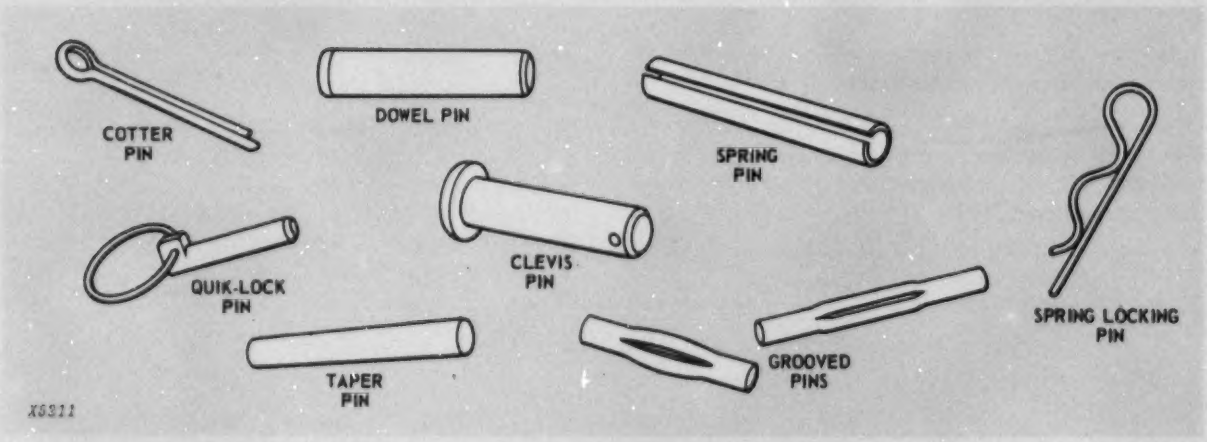

Fig. 144 — Some Frequently Used Pins

Few manufacturers of machines and similar products could get along without pins (Fig. 144) of one kind or another. In their many forms, pins are convenient fasteners, utilized in many ways.

CLEVIS OR HEADED PINS

The simplest pin, perhaps, is a headed pin, sometimes called a *clevis* pin because it is used to attached a part to a U-shaped yoke known as a *clevis* (Fig. 143).

Headed pins are usually drilled on the end opposite the head for insertion of a cotter pin or one of several types of special "convenience" pins (see page 47).

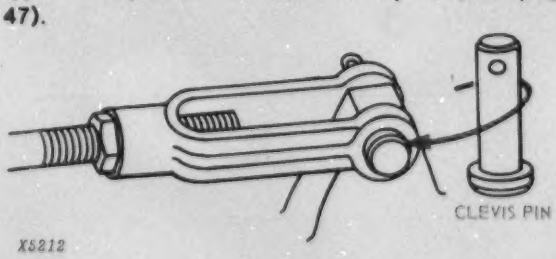

Fig. 145 — A Clevis Pin Used to Attach a Yoke

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PIVOT PINS

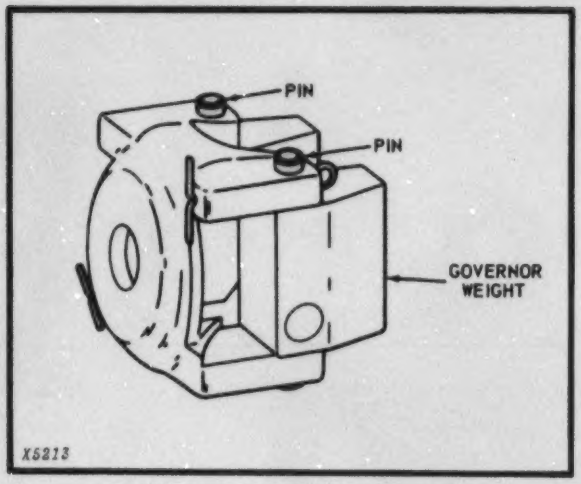

Fig. 146 — Pins for Governor Flyweights

Some pins serve as small axles on which parts may pivot. The pivots for the governor flyweights on a tractor or combine engine (Fig. 146) are good examples of these pins. Pivot pins are usually headless and are drilled or grooved for cotter pins or snap rings.

These pins require exact fitting and are often tight in their holes. Their diameters may be expressed in thousandths of an inch instead of fractions.

When tight-fitting pins are to be removed, they must be driven out with a hammer and *pin punch* that's nearly the size of the pin.

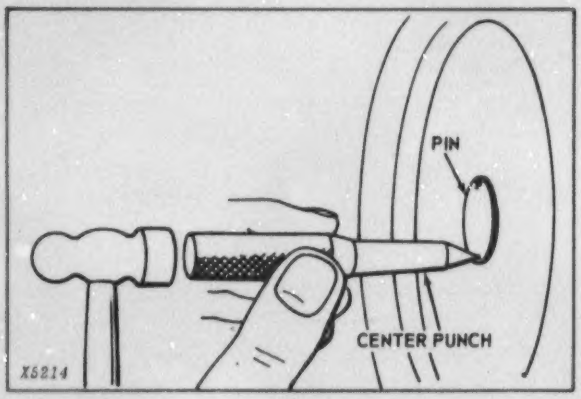

Fig. 147 — Staking a Pin to Hold It in Place

Pins are often *staked* in place (Fig. 147) so they won't fall out. A small center punch is used for this purpose. Striking the punch with a hammer "upsets" the pin and causes it to swell slightly, pressing it firmly against the sides of the bore.

TAPER PINS

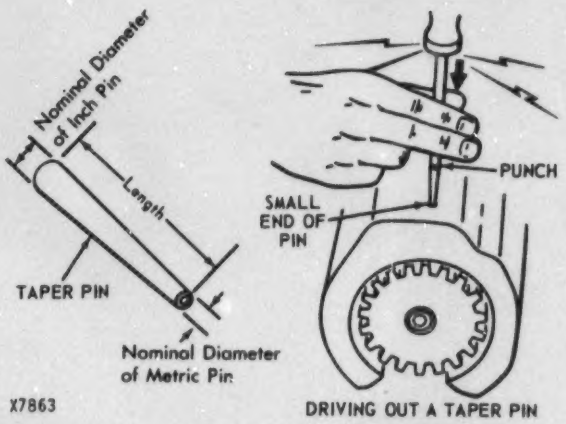

Fig. 148 — A Taper Pin and How It is Removed

Parts that must fit tightly are often fastened together with a *taper* pin (Fig. 148). The taper helps to line up the holes in the parts being assembled. The pin is driven into a specially reamed hole until it is fully seated. Standard inch-size taper pins taper at the rate of 1:48 and are designated by overall length and the diameter of the *large* end. Standard metric pins taper at a rate of 1:50 and are designated by overall length (mm) and diameter of small end (in mm).

Taper pins are driven out with a hammer and a punch held against the small end of the pin (Fig. 148).

DOWEL PINS

Dowel pins are frequently used to assure that fastened parts align *exactly* as they are supposed to, and to make parts alignment easier, much like a stud.

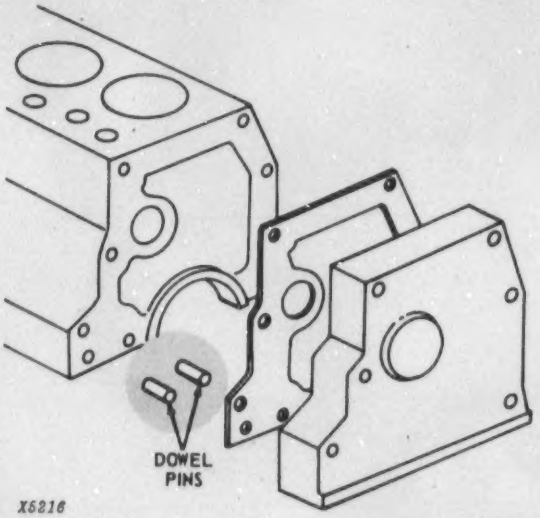

Fig. 149 — How Dowel Pins Line Up Parts for Easy Assembly

The use of dowel pins to line up the timing gear cover and gasket with the crankcase of an engine is a good example. See Fig. 149, previous page.

A dowel pin is a tiny bit larger in diameter than the hole into which it is to go, so it must be pressed or driven in. Once in place the press-fit assures that the pin will not come out.

The outer end of a dowel pin projects above the surface of the part into which it is pressed and mates with other holes in the parts to be assembled.

Inch-size pins are hardened and ground to accurate diameters ranging from ⅛ to ⅞ inch. Standard dowel pins are ground 0.0002 inch oversize (two ten thousandths of an inch) to assure a press fit.

The nominal diameter of a metric dowel pin is the size of the hole the pin is designed to fit. The actual diameter is slightly oversized to assure a press fit. Metric diameters range from 3 mm to 100 mm.

Dowel pins are usually permanently installed and need not be replaced unless they are damaged.

SPRING PINS

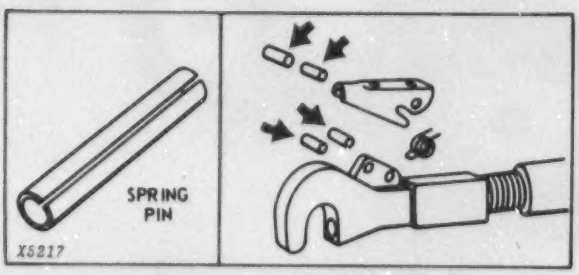

Fig. 150 — Spring Pins in a Tractor 3-Point Hitch

Spring pins (Fig. 150), often called rollpins, give manufacturers a quick, convenient, inexpensive means of fastening parts where loads are not unduly great. Approximately 104 spring pins are used in one model of a modern farm tractor. This will give you some idea of their importance. The pins that hold the hook parts on a tractor 3-point hitch (Fig. 150) are good examples.

Slotted spring pins are hollow cylinders of spring steel. They are split lengthwise and chamfered on both ends for easier "starts." Metric slotted spring pins may be chamfered on only one end. Coiled springs are rolled up spring steel chamfered on both ends.

These pins are made slightly oversize so when they are driven or pressed into place they are compressed and their attempts to expand hold the parts firmly in place.

The diameter and length of spring pins are expressed in inches and fractions of inches.

To remove a spring pin, drive it out of its hole with a punch just a littler smaller in diameter than the hole.

GROOVED PINS

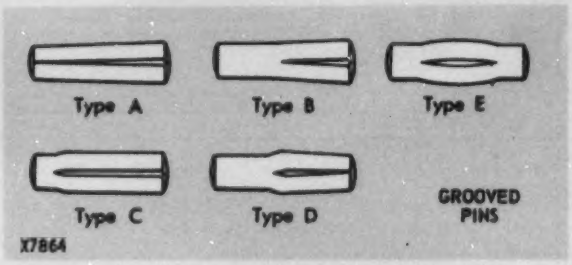

Fig. 151 — Types of Grooved Pins

Grooved pins (Fig. 151), like spring pins, are handy fasteners for many parts. However, they are made of solid material with slots, or grooves, cut along all or part of their length. They, also, depend for their holding power on expansion force developed as they are compressed when driven into place.

Grooved pins come in various shapes and sizes, designated by standardized "types." Type designations are letters — A, B, C, etc. The ones most often used are illustrated in Fig. 151.

Type A is used for general purpose fastening.

Type B is used mainly as a hinge, but can also be used where a locking fit over only part of the pin is required.

Type C has a "pilot" end to guide it into the hole.

Type D is useful when a pin must be assembled into a "blind" hole (one that is not drilled all the way through).

Type E is used when the locking action must be in the pin's center portion. It is sometimes used instead of a cotter pin.

Other types are available for special purposes.

The diameter and length of grooved pins are measured in inches and fractions of inches (or millimeters). The nominal diameter of the pin is equal to the diameter of the hole in which it will be placed.

CONVENIENCE PINS

There are several types of pins that are of a nonpermanent nature; in fact, they are made especially for quick and easy removal.

Spring Locking Pins

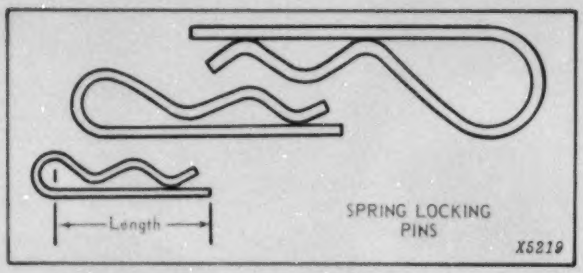

Fig. 152 — Examples of Typical Spring Locking Pins

One of these is the *spring locking pin* (Fig. 152) often called a *hairpin cotter*. These simple pins, which come in various shapes and sizes, are useful when parts must be separated for operating adjustments, or when attachments are installed and then removed when they are no longer needed.

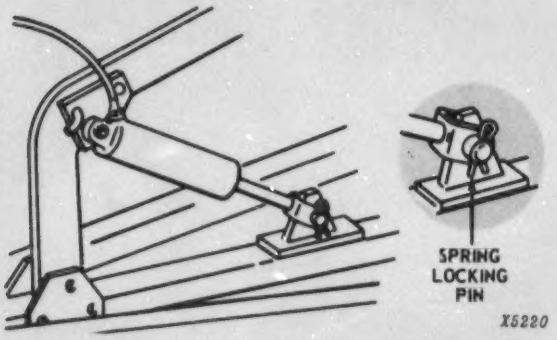

Fig. 153 — Spring Locking Pins Used to Attach A Remove Hydraulic Cylinder

Usually a spring locking pin is inserted into a hole drilled through a *clevis* pin after the clevis pin has been installed to hold parts together. The clevis and spring locking pins that attach remote hydraulic cylinders to many farm implements (Fig. 153), such as large disk harrows, are just one of the many examples.

Spring locking pins are measured by the size of wire from which they are made, and by the distance from the center of the top loop to the end of the point.

Quik-Lock Pins

Another handy "convenience" pin is the quik-lock pin (Fig. 154). It has many uses when one part is to be attached temporarily but securely to another. One such use you may frequently encounter is hitching an implement to the drawbar of a tractor or other prime mover. Another use is, like a spring locking pin, to fasten attachments which may later be removed. A good example is the use of these handy pins to fasten 3-point hitch parts to an industrial backhoe-loader.

The interesting feature of quik-lock pins is a split steel ring. The ends of the ring are thrust into two holes drilled in different planes in the pin head. Once the pin is inserted in place, the steel ring is rotated down and around the end of the clevis pin (Fig. 154). The difference in the position of the ring end develops an "over-center" spring action which holds the ring firmly around the clevis pin and the quik-lock pin cannot come out.

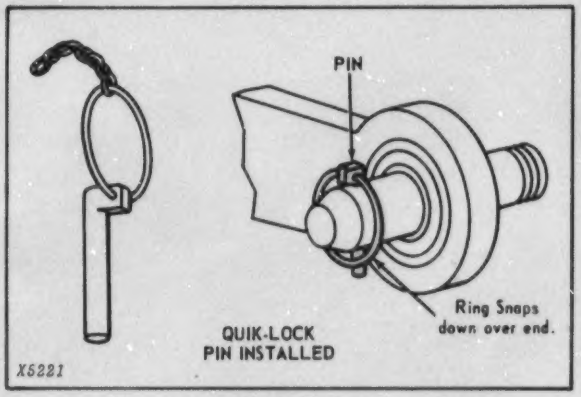

Fig. 154 — Quik-Lock Pin Properly Installed

Some quik-lock pins have a short chain which can be fastened to a convenient nearby part to keep the pin from becoming lost.

Quik-lock pins are identified by diameter and length in inches and fractions of inches.

SHEAR PINS

Sometimes it is important that a pin be just strong enough to carry the *normal* load imposed upon machine elements like rotating parts. Such a pin is called a *shear pin*. It acts as a safety device and will shear, or be cut off, when heavily overloaded, preventing more serious damage to other parts of

the machine. If you own a boat and outboard motor, the chances are the propeller is protected from damage, if it strikes a heavy object, by a brass shear pin (Fig. 155).

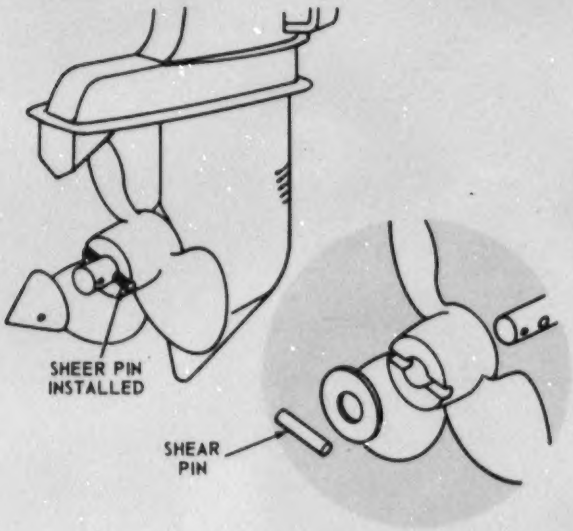

Fig. 155 — Shear Pin in an Outboard Motor Propeller

SNAP RINGS

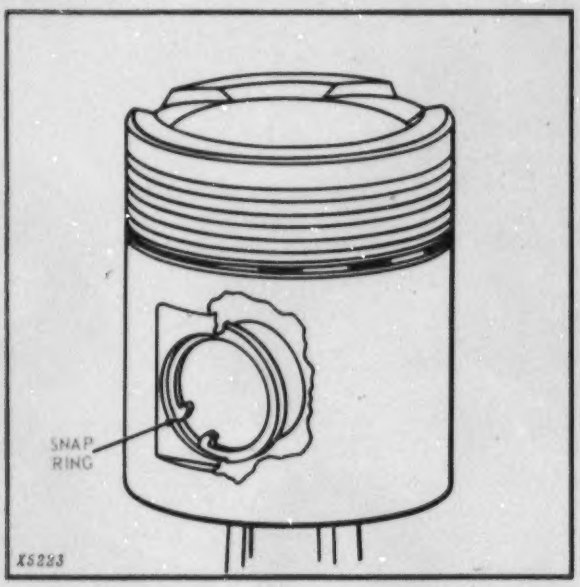

Fig. 156 — A Snap Ring Secures the Wrist Pin in a Piston

There are many applications where there's a need for a removable *shoulder* to accurately locate, retain, or lock components on shafts and in bores and housings. A good example is the wrist pin that connects the connecting rod to the piston in an internal combustion engine (Fig. 156).

The wrist pin is kept from slipping out of its bore by a spring steel *snap ring* at each end. The snap ring fits into a circular groove in the wrist pin hole in the piston wall near the end of the pin.

Because these rings keep parts in place, they are often called *retaining rings* or *lock rings*.
There are two basic styles of snap rings: internal and external.

INTERNAL SNAP RINGS

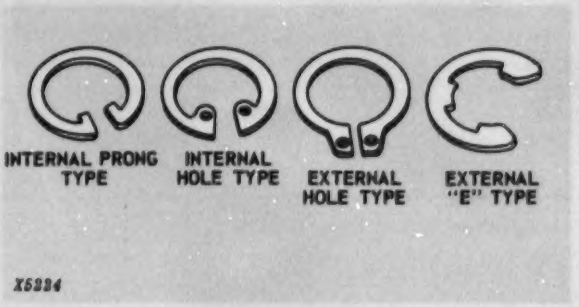

Fig. 157 — Typical Snap Rings

Internal snap rings (Fig. 157), like the wrist pin retainer described above, fit *inside* a hole and so are called "internal."

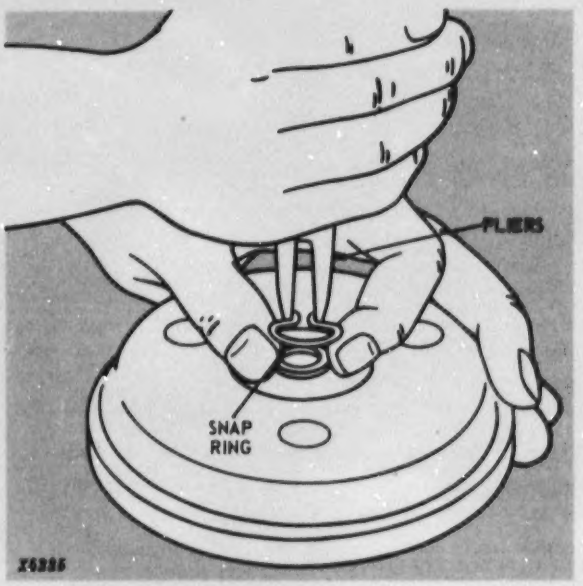

Fig. 158 — Removing an Internal Snap Ring

The prong-type ring is removed or installed by grasping the two prongs with pliers and compressing the ring until it slips from its groove. Fig. 158 shows an internal snap ring being removed from

the drive plate of the compressor for a modern tractor or combine air conditioner. To install the ring, it is compreased and inserted into its groove. When released, it will spring outward and firmly seat itself in the groove.

Another type of internal snap ring has two holes that can be engaged by the tips of a special snap ring plier (Fig. 158, previous page).

EXTERNAL SNAP RINGS

External snap rings are installed around a shaft, rather than in a groove around a hole. Many bearings are located on and locked to their shafts this way.

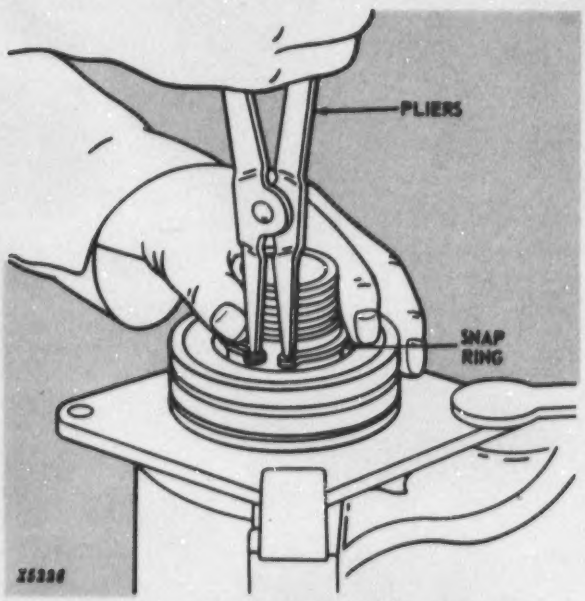

Fig. 159 — Removing an External Snap Ring

Most external rings are removed and installed by means of a special plier. The jaws on this plier *open up* (Fig. 159) when the handles are squeezed, instead of closing as do the jaws on regular pliers.

Small shafts are often locked in place with an external "E" snap ring (Fig. 157, previous page), usually removed or installed with ordinary pliers.

Snap rings can be formed out of wire or can be punched from flat material. They are generally reusable unless they are damaged or broken.

In addition to the snap rings described and illustrated, there's a wide variety of shapes and sizes, too numerous to be discussed in this manual. There are so many that if a replacement is needed, it must be accurately identified.

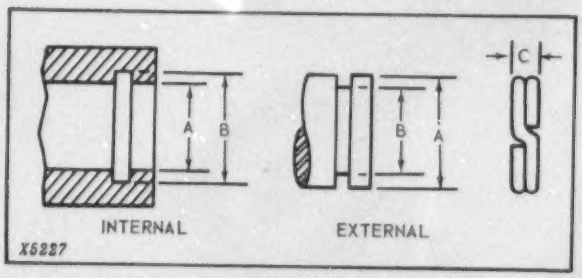

Fig. 160 — How Snap Rings Are Measured

Typical measurements are bore diameter (A, Fig. 160), groove diameter (B), and ring width (C). Note that "A" is the *inside* diameter and "B" the *outside* diameter of internal snap rings. In the case of external rings, "A" is the *outside* diameter and "B" the *inside* diameter.

In addition to measurements, snap rings are identified by appearance and prong design.

RIVETS

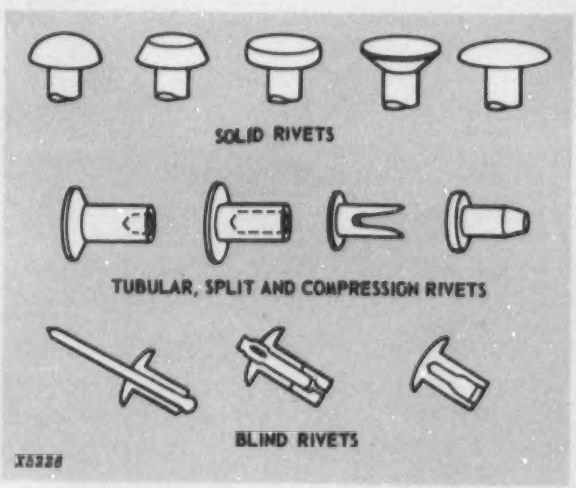

Fig. 161 — Some Frequently Used Rivets

A very useful family of fasteners consists of rivets — soft metal pins with a head on one end (Fig. 161). They are low in cost, installed at high-speed, permanent, and versatile.

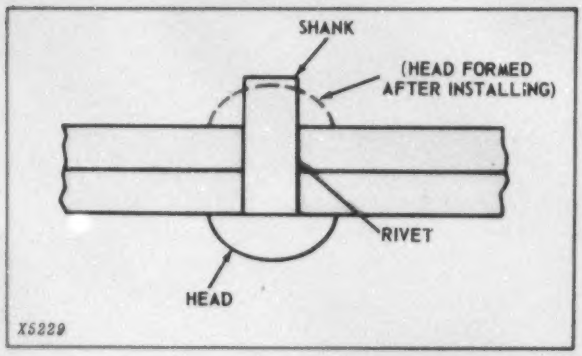

Fig. 162 — How Rivets Are Installed

Common solid rivets are used primarily to hold two or more flat, parallel parts together. The parts are drilled or punched, a rivet inserted into the matching holes (Fig. 162), and a second head formed on the other end of the rivet, called the *shank*.

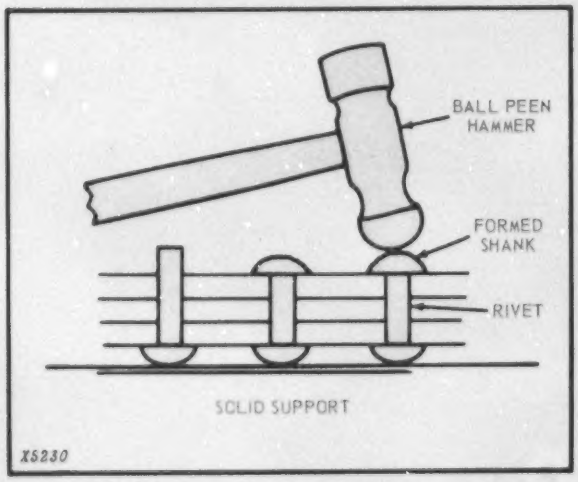

Fig. 163 — Peening the Second Head of a Rivet

A large shop may have a riveting machine to form the second head. More commonly, the second head is peened or formed by a mechanic using a *ball peen* hammer (Fig. 163). While doing this, the rivet head must be "bucked" or pressed against something solid as the second head is formed; otherwise, it will not grip securely.

Like other fasteners, rivets come in many sizes with a variety of head shapes. Some of the most common are illustrated in Fig. 164.

The size of rivets in common use ranges from 3/32 inch to 1½ inches (1 to 36 mm) in diameter and most any practical length. A ⅞-inch (or 22 mm) diameter rivet is about the largest that can be peened by hand.

BLIND RIVETS

These useful fasteners, intended only for light duty usage, can be installed in a joint which is accessible from one side only. This construction is often said to have a "blind hole." There are several types of blind rivets.

One type in common use requires a special tool to install it. After the rivet is inserted, the tool pulls a stem up through the hollow center and forms the second head (Fig. 165); the stem is then broken off.

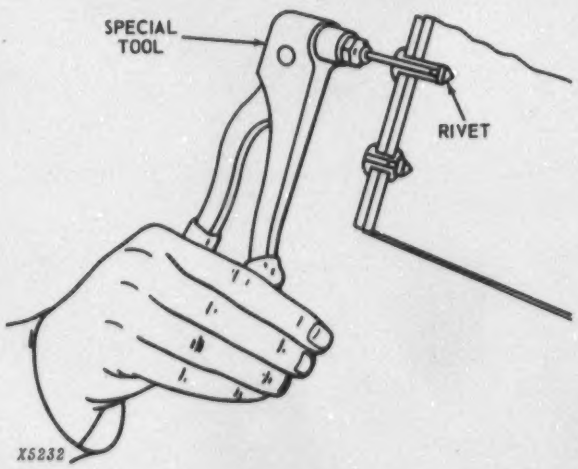

Fig. 165 — Installing a Special Rivet in a "Blind" Hole

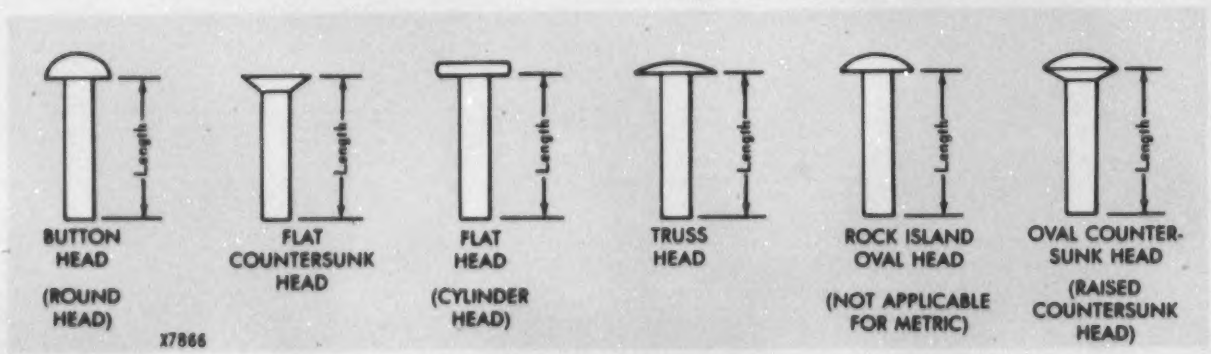

Fig. 164 — Typical Rivet Head Styles (Metric Nomenclature in Parentheses)

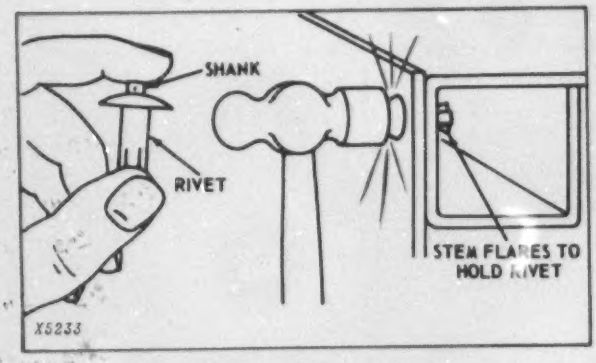

Fig. 166 — Installing Another Type of "Blind" Rivet

Another type of blind rivet also has a stem, but instead of pulling on it, the stem is driven into the rivet (Fig. 166). The stem flares the lower end of the rivet to hold it firmly in place.

A third type of blind rivet, which may not be encountered frequently in the average shop, but is of interest, is the chemically expanded or *explosive* rivet.

This one-piece rivet has a hollow end filled with an explosive. When heat or an electric current is applied to the rivet head, the explosive detonates and expands the walls of the rivet body to form blind end.

CLAMPS

Clamps compose a large family of useful fasteners, most of them relatively simple and easy to use.

HOSE CLAMPS

As their name implies, these clamps (Fig. 167) are used in many applications to secure hose ends to metal pipes. The important thing about hose clamps is to get them tight when installed so they won't leak fluid or air and won't allow the hose to work loose from the pipe due to slight relative motion or vibration.

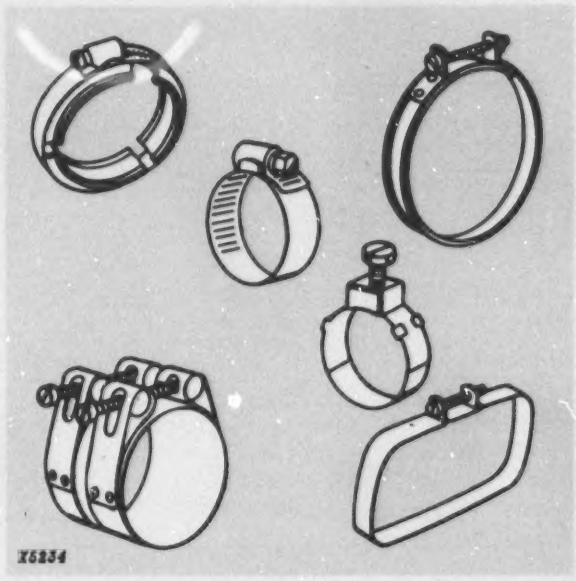

Fig. 167 — Some of the Many Styles of Hose Clamps

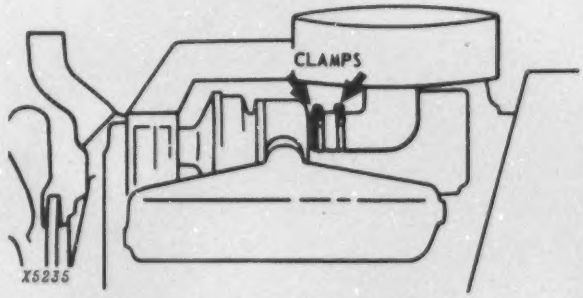

Fig. 168 — Hose Clamps on Hose Connecting Air Cleaner to Turbocharger

In some applications, clamps are used to secure the hose that joins the air cleaner to the turbocharger on a modern diesel engine (Fig. 168). It is extremely important that these clamps be tight at all times because if the hose ends leak, they can let dust or other foreign matter enter where it can easily damage the precision-built turbocharger with its close-fitting parts.

FOS — 60 Litho in U.S.A.

WIRE ROPE CLAMPS

For years wire rope has been used for many purposes. Usually one or both ends of a length of wire rope must be anchored to something. For this purpose a loop is formed and the free end is fastened with a wire rope *clamp* (Fig. 169).

The size and strength of the clamp is matched to that of the cable.

Generally two or more clamps are used to provide a safety factor.

Often a metal "eye" (Fig. 169) is inserted into the loop to provide a wearing surface and to maintain the shape of the loop.

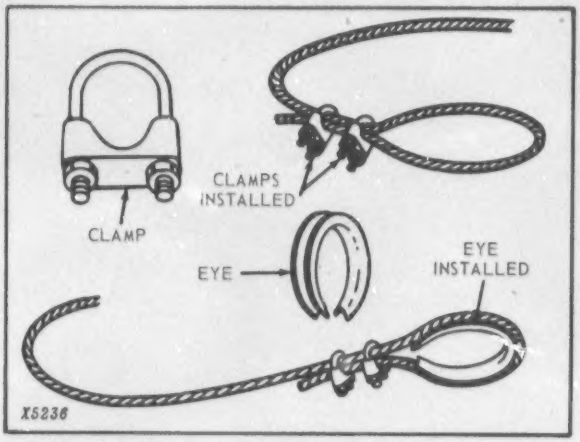

Fig. 169 — A Wire Rope Clamp

TEST YOURSELF

QUESTIONS

1. Name three types of heads commonly found on machine screws.
2. What are other names for tapping screws?
3. Is "dog-point" the name of one style of set screw?
4. What is the shape of a Woodruff key?
5. Are tools available for installing and removing studs?
6. Clevis, pivot, taper, dowel, spring, grooved, spring locking, quik-lock, shear are names of certain fasteners. What are they?
7. What is one use for dowel pins?
8. Some pins are especially made to fail when overloaded. Name them.
9. There are two basic types of snap rings. What are they?
10. What kind of hammer is usually used to install a common iron rivet?

(Answers on page 71.)

SPECIALTY AND PLASTIC FASTENERS/PART 5

SPECIALTY FASTENERS

A host of specialty fasteners has become available, as the need for them arose, to work with modern, sophisticated components and assemblies. Many of these were developed to speed assembly, reduce cost, and to make removal quick and easy.

Only a few of these fasteners — the ones most encountered — will be mentioned in this manual.

DART-TYPE SPRING CLIPS

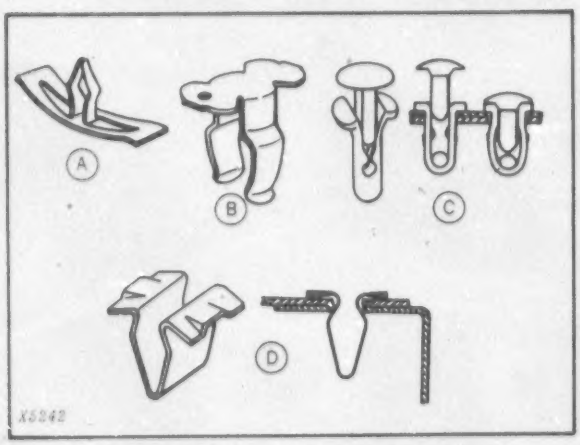

Fig. 170 — Examples of Dart-Type Spring Clips

This family of fasteners (Fig. 170) performs several functions, valuable in manufacturing processes, by replacing several parts (a bolt, washer and nut, for instance), thus reducing assembly time and cost. Because they are under spring tension when installed, they won't loosen when subjected to vibration.

Most spring clips are made of steel, hardened and tempered. However, an increasing variety of plastic clips is being used when holding capacity is not critical.

Fig. 170 shows a few representative spring clips. A brief description of each follows:

Clip A has moderate holding power and will not damage delicate components.

Clip B has more strength.

Clip C is a plastic clip that insulates, is easy to insert, and is reusable.

Clip D is a heavy-duty dart with raised portions in the head where a screwdriver can be inserted to pry it up.

CABLE AND TUBE RETAINERS

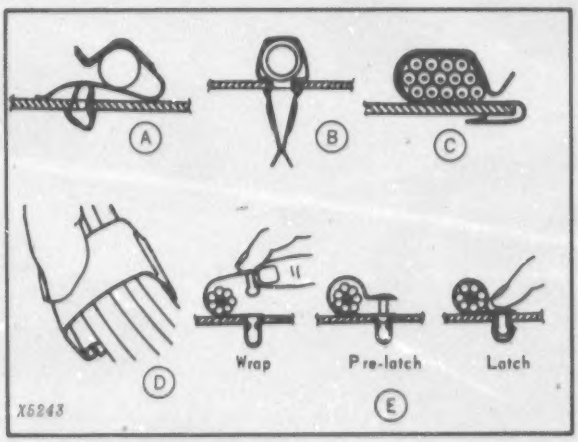

Fig. 171 — Cable and Tube Clips

These fasteners (Fig. 171) are frequently used to hold bundled wires, wire harnesses, and tubes in place. They can be installed from the front; it's not necessary to have access to the back of the panel or other part. Because they fasten through spring tension, like spring clips, they will not loosen under vibration.

The features of the clips shown in Fig. 171 are listed briefly below.

Bundle Holder A has separately formed dart-type mounting.

Simpler Clip B has an enlarged upper section.

Two-Armed Clip C holds on to panel edge with one barbed arm while holding bundle in the other.

Adhesive-Backed Clamp D retains wire harnesses without the need for a panel hole.

Flexible Plastic Clamp E is self-retaining and can be used with various cable sizes.

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QUICK-OPERATING FASTENERS

These handy fasteners are used where repeated access is necessary. Four frequently used types are discussed briefly here and illustrated in Fig. 172.

- **Lever-actuated**
- **Turn-operated**
- **Slide-Action**
- **Push-pull**

Lever-Actuated **fasteners (Fig. 172) draw and pull the two elements being joined together, then locks by pivoting over center.**

Turn-Operated **fasteners consist of a stud- or pawl-like part and another part to hold the stud or pawl in place. The operation of most of them is explained by a glance at the illustration. The J-**

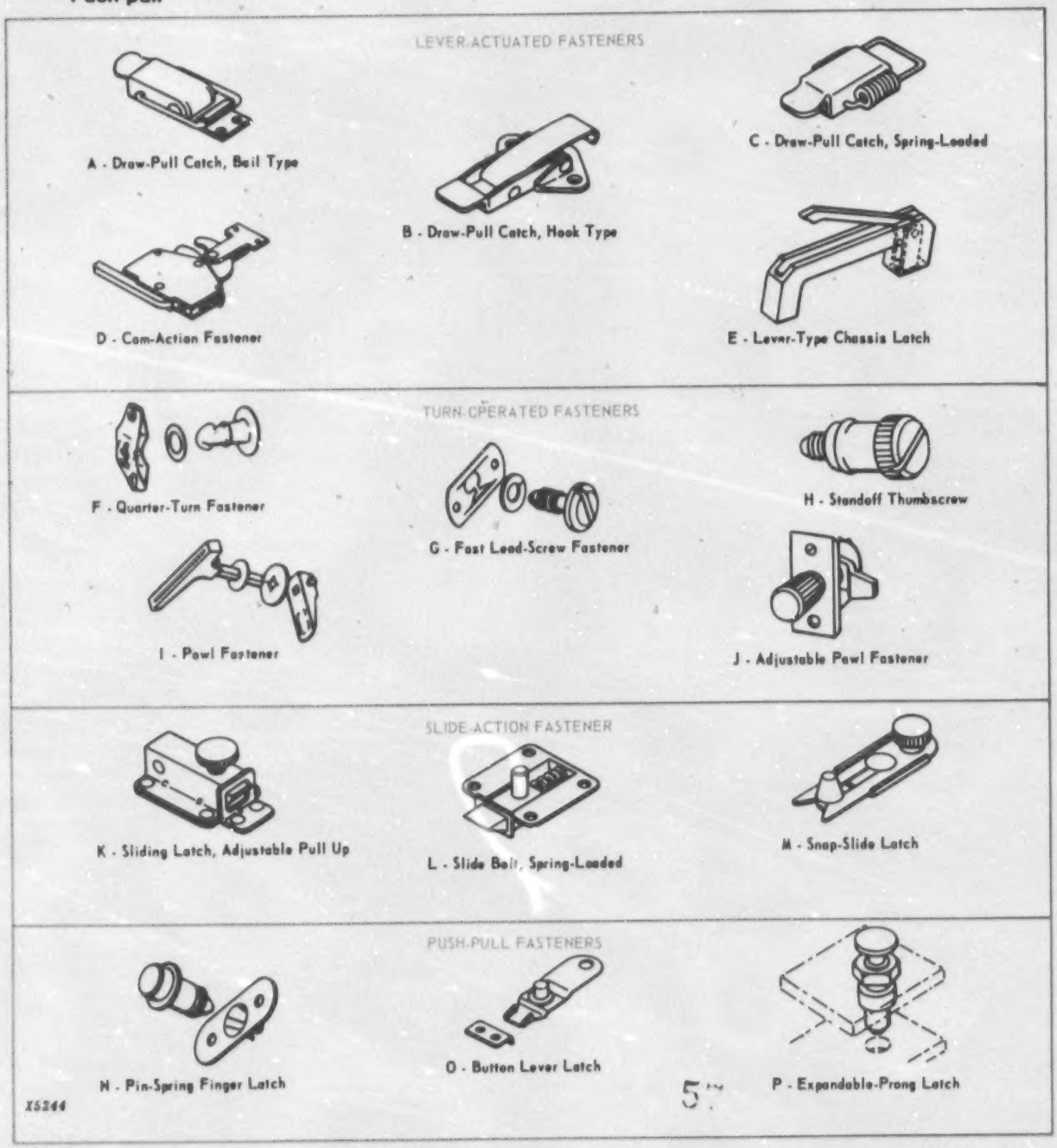
LEVER-ACTUATED FASTENERS
A - Draw-Pull Catch, Bail Type
B - Draw-Pull Catch, Hook Type
C - Draw-Pull Catch, Spring-Loaded
D - Cam-Action Fastener
E - Lever-Type Chassis Latch
TURN-OPERATED FASTENERS
F - Quarter-Turn Fastener
G - Fast Lead-Screw Fastener
H - Standoff Thumbscrew
I - Pawl Fastener
J - Adjustable Pawl Fastener
SLIDE-ACTION FASTENER
K - Sliding Latch, Adjustable Pull Up
L - Slide Bolt, Spring-Loaded
M - Snap-Slide Latch
PUSH-PULL FASTENERS
N - Pin-Spring Finger Latch
O - Button Lever Latch
P - Expandable-Prong Latch
X5244

Fig. 172 — A Few Typical Quick-Operating Fasteners

Type can be self-compensating for a wide range of material thicknesses by means of a threaded shaft along which a pawl moves when the shaft is rotated. This type provides good compressibility or "pull-up" and is often used with gaskets or where very tight lock-down of one part to another is desirable.

Type I has a pawl that slides along a shaft to a pre-determined position where it can be locked in place with a nut or set screw.

Slide-Action fasteners have many applications in almost every home and shop. They are frequently used for cabinet doors or drawers and the like. Most have a sliding bolt-like part usually enclosed within a housing. The bolt-like part can be moved across the edge of a closure to engage a "keeper" usually mounted to the frame or body of the structure. Sometimes a keeper isn't used, and the bolt engages directly into the surface of the frame or panel.

Push-Pull fasteners usually consist of an operating button or knob connected through a panel to a locking device on the opposite side of the panel. They are designed for applications requiring quick access without use of special tools and where space limitations or other factors make lift, turn, or slide action undesirable. These fasteners are usually latched by pressure, either upon a panel or the latch button. A push on the button or a pull on the knob disengages the fasteners.

There are many variations of these fasteners but most require the following combinations of manual operations:

- **Push to lock — push to release.**
- **Lock on closing — push to release.**
- **Push to lock — pull to release.**
- **Pull to lock — pull to release.**

When these fasteners are used, some play or clearance must usually be permitted between a panel and frame in the latched position, since these fasteners are not intended to pull up or compress the panel to the frame or against a seal.

PLASTIC FASTENERS

The impact of plastics on our everyday lives is easily proved by a glance around you which will surely reveal one or more plastic or plastic-containing objects. It was natural that the development of plastic fasteners (Fig. 173) should proceed, hand-in-hand, with the development of other plastic products.

Plastic fasteners are mechanical devices — bolts, nuts, screws, rivets, and specialty parts, made from plastic and designed to hold, join, couple, assemble, or maintain the equilibrium of single or multiple components.

The basic differences between metal and plastic fasteners are the materials and the manufacturing processes. Otherwise plastic products — nuts, bolts, screws, rivets — conform to the same dimensional, thread class, and fit standards as those for metal fasteners. See American National Standards Institute (ANSI) standards (page 7).

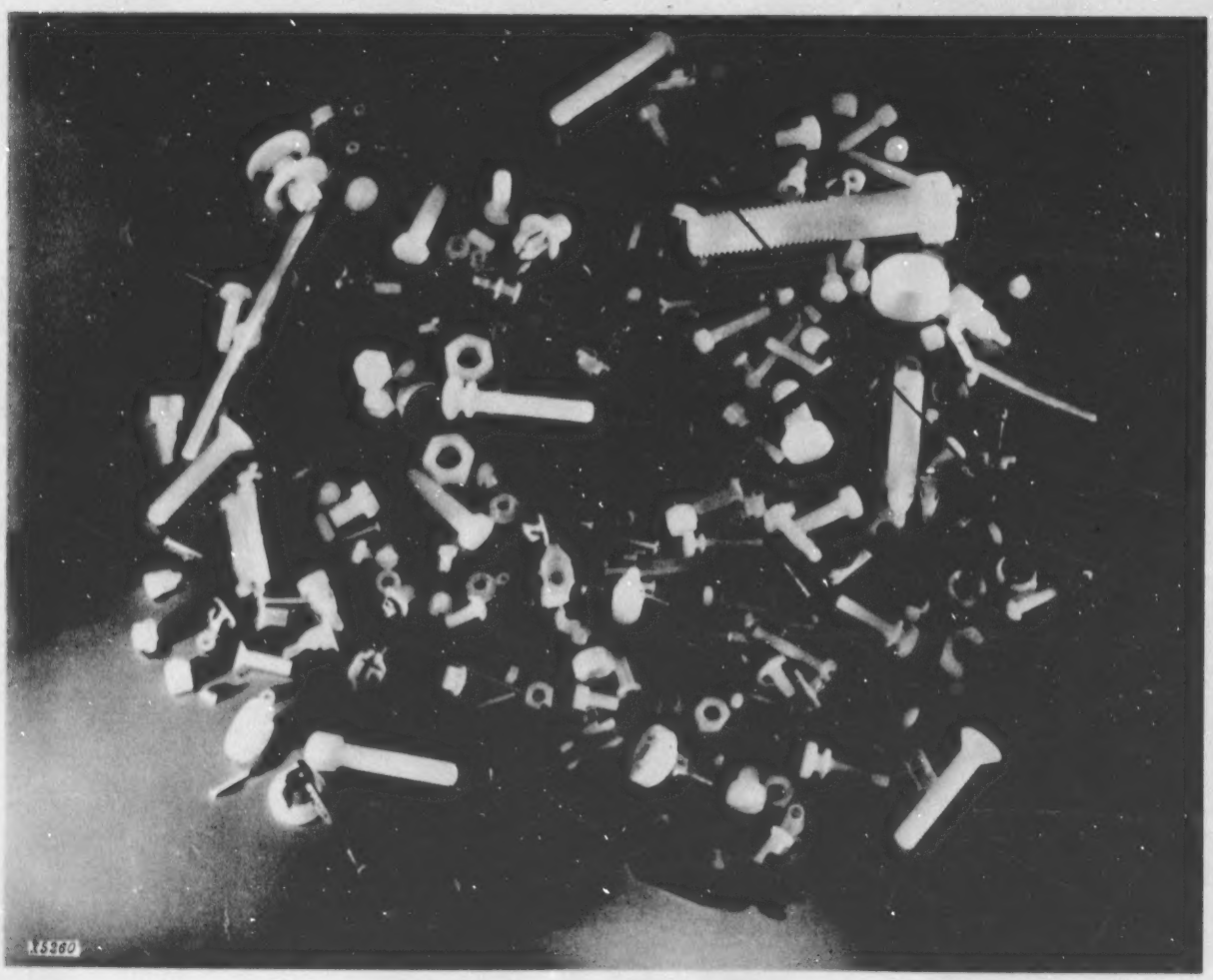

Fig. 173 — Plastic Fasteners Ad Infinitum

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PROPERTIES

Plastics are noted for their good combination of qualities. They can, for example, all at the same time, be strong, lightweight and flexible. Because of these and other properties, plastic fasteners provide the following benefits given below.

ADVANTAGES OF PLASTIC FASTENERS

- **Long life**
- **Low maintenance**
- **Design flexibility**
- **Corrosion resistance**
- **Nonelectrical conductance**
- **Self-locking capacity**
- **Self-sealing capacity**
- **Nontoxicity**
- **Light weight**
- **Chemical resistance**
- **Self-lubrication**
- **Antimagnetic properties**
- **Dent and scratch resistance**
- **Nonflammability**
- **Fast assembly**

TEST YOURSELF

QUESTIONS

1. What are two important reasons for using dart-type spring clips?

2. There are four common types of quick-operating fasteners. What are they?

3. Do most plastic fasteners conform to American National Standards Institute (ANSI) standards?

4. Name four valuable features of plastic fasteners.

(Answers on page 71.)

Is it any wonder that so many plastic fasteners have become much a part of our everyday lives?

CLASSIFICATION

Plastic fasteners are classified the same as metal fasteners: externally threaded, internally threaded, and nonthreaded.

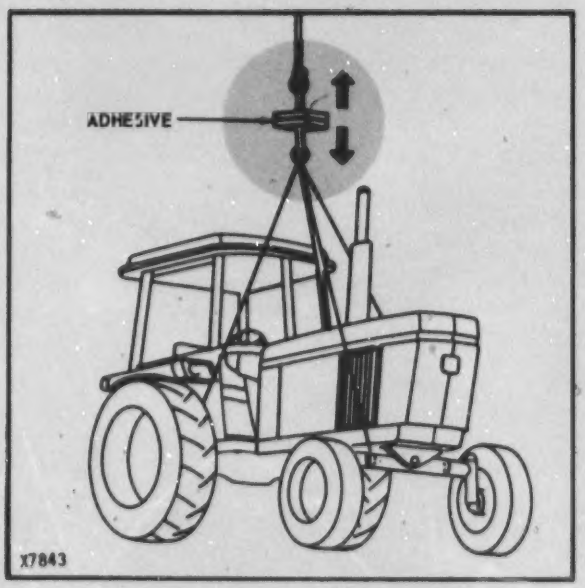
Externally threaded plastic fasteners, like their metal counterparts, are classified as bolts, screws, rods, and studs, and are used for the same purpose.
— Bolts for insertion through holes in assembled parts to mate with a nut.
— Screws, rods, and studs for insertion into holes to mate with preformed internal threads or with nuts.

Internally threaded plastic fasteners are intended for use on bolt or screw threads and are normally known as nuts.

Nonthreaded fasteners make up a broad group of plastic fasteners generally classified by product families — rivets, washers, pin fasteners, quick-operating fasteners, retaining rings, inserts, spacers, clips, harnesses, clamps, wirebundlers and ties, snap-inserts, grommets, and so on and on.

ADHESIVES AND SEALANTS/PART 6

ADHESIVES



174 — Adhesives Are Extremely Strong

During recent years *adhesives* have become a very important type of fastener in manufacturing and other processes. They are extremely versatile, strong, and have many desirable qualities, some of which will be mentioned a little later.

You are not likely to become involved with adhesives except for the household or shop varieties that come in small quantities in bottles, cans or tubes. However, they are used so extensively that this book on fasteners would be incomplete without a brief discussion of them.

HISTORY OF ADHESIVES

Adhesives are one of the oldest joining materials. They are known to have been used by the Babylonians over 6000 years ago, and by the Egyptians at least 3400 years ago who saturated the linen bandages in which they wrapped mummies with resins and waxy gums to protect both body and wrappings from deterioration.

Most primitive adhesives came from tree sap, leaves, bark, roots and bones. Indeed, these were the raw materials for all adhesives until the first part of the present century. (Remember Grandpa's old glue pot?) Then, during the scientific explosion of this century's second quarter, the development of synthetics and plastics led to a whole host of adhesives until now there are literally thousands of them. And the quantity of adhesive used in many forms for many fastening jobs is almost astronomical — it is estimated at over two billion pounds a year. Indeed, this can be called the "Adhesive age."

Some adhesives have such general use that their names are familiar to most everyone who likes to make or repair things. Such names as epoxy, silicones, styrene, nylon, acrylics, vinyl, neoprene, urethane, phenolics, polyester, have become household words — they are all adhesives or are basic ingredients in adhesives.

WHAT IS AN ADHESIVE?

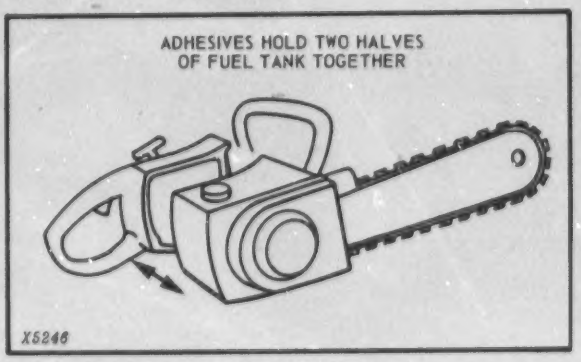


Fig. 175 — The Two Halves of This Chain Saw Fuel Tank Are Fastened Together With an Adhesive

An adhesive is a substance capable of holding materials together *in a useful manner* by surface attachment (Fig. 175).

Adhesive bonding differs from most other joining methods in that no other fasteners, such as rivets or bolts, are used to hold components together.

Today manufacturers are using and relying on adhesive more and more. Thousands of products are assembled wholly or in part with adhesive products. Look around your home and shop. Chances are you'll spot a half dozen products that depend on adhesives at least in part to hold them together.

USES FOR ADHESIVES

The main function of adhesives is mechanical — they fasten. But they perform other jobs, too. For instance, sometimes they seal, or insulate against heat and cold or electricity. (On the other hand, some adhesives can be formulated that *improve* thermal and electrical conductivity.)

Often adhesives help to reduce corrosion, damper vibration and resist fatigue.

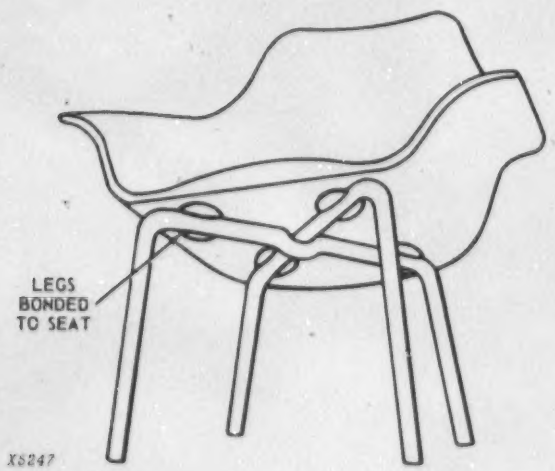


Fig. 176 — The Legs of This Modern Chair Are Adhesive-Bonded to the Seat. There Are No Bolt or Rivet Heads to Cause Discomfort.

Usually they do not change the contour and appearance of the parts they join. Unlike bolts or rivets, adhesives give little or no visible evidence that they are there (Fig. 176).

Another use is to permit the bonding of dissimilar parts, and the fabrication of unique and complex assemblies that would be very difficult to manufacture with more conventional fasteners.

A property somewhat related to an adhesive's ability to damp vibration is resistance to fatigue. A properly selected adhesive generally can withstand strains, brought about by repeated stresses, without developing failure-producing cracks. In a well designed joint, the fastened parts generally fail in fatigue before the adhesive.

Adhesives transmit stresses from one member of a joint to another, resulting in a more uniform stress distribution than is obtainable by use of mechanical fasteners. Because of this, adhesives often permit fabrication of structures mechanically equivalent to or surpassing conventional assemblies, and at less cost and weight.

Adhesives when performing their major fuction — holding — are always parts of a structure or composite. They do not function as separate entities, but as materials that influence, and are themselves influenced, by the materials which they contact.

Adhesives can also produce joints with high strength, rigidity, and precision in light metals such as aluminum and magnesium, which may be distorted by welding.

In summary, the uses to which adhesives can be put are almost limitless; the space age has taken advantage of their versatility in thousands of products, as have most other industries. And the need for more adhesives arises each day. For instance, the U. S. Government, at one time, needed a nontoxic adhesive for bonding contact lenses on sharks' eyes. Chances are a satisfactory adhesive was developed.

But there's another side to the coin —

LIMITATIONS OF ADHESIVES

Useful and versatile as they are, adhesives *do* have their limitations.

It takes many hundreds to meet the exacting requirements. Unfortunately an adhesive does not exist that will bond everything to anything with equal utility.

Unlike other fasteners, an adhesive is not independent of its environment.

Many adhesives are affected adversely by environmental factors such as temperature, humidity,

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some vapors and liquids. They often perform poorly when subjected to simultaneous applications of moisture and stress.

Although moderate exposure to common fluids (such as water, lubricants, oil and solvents) have little effect on a carefully chosen adhesive, most of them are considered to be weakened by exposure to sunlight and heat.

Many adhesives have to be "cured" or allowed to harden over a lengthy period of time. This may not be practical or desirable in some manufacturing processes.

JOINTS USING ADHESIVES

It is true that the greatest use of adhesives is in the manufacture of products, and you'll seldom be called upon to use them in the shop or home except, of course, for simple repair jobs. However, occasions may arise when you'll want to make something with joints bonded together with an adhesive. While planning your project, take into consideration what the joint must accomplish and the stresses it may be subjected to. Then choose the type of joint that will best serve your purpose.

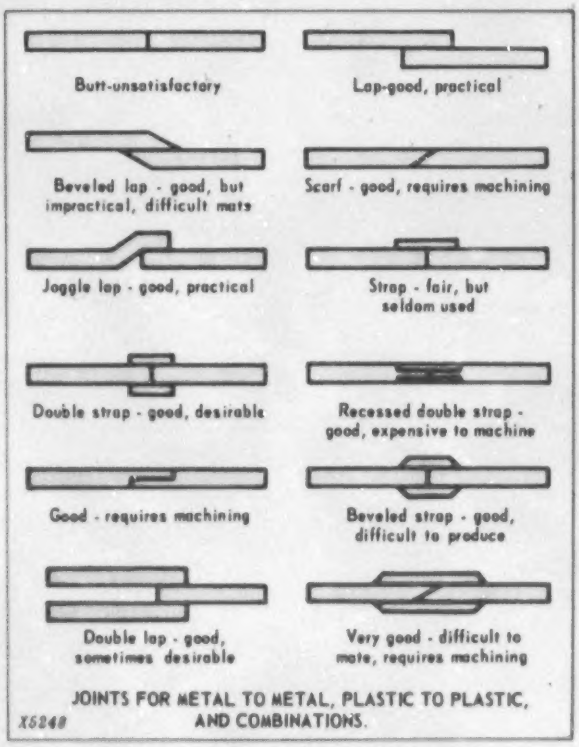
Butt-unsatisfactory
Lap-good, practical
Beveled lap - good, but impractical, difficult mate
Scarf - good, requires machining
Joggle lap - good, practical
Strap - fair, but seldom used
Double strap - good, desirable
Recessed double strap - good, expensive to machine
Good - requires machining
Beveled strap - good, difficult to produce
Double lap - good, sometimes desirable
Very good - difficult to mate, requires machining
JOINTS FOR METAL TO METAL, PLASTIC TO PLASTIC, AND COMBINATIONS.
X5248

Fig. 177 — Typical Joints — Some Good, Others Unsatisfactory

Fig. 177 illustrates some typical joints and explains their advantages and disadvantages. These are not, of course, the limit of possible bonded joints.

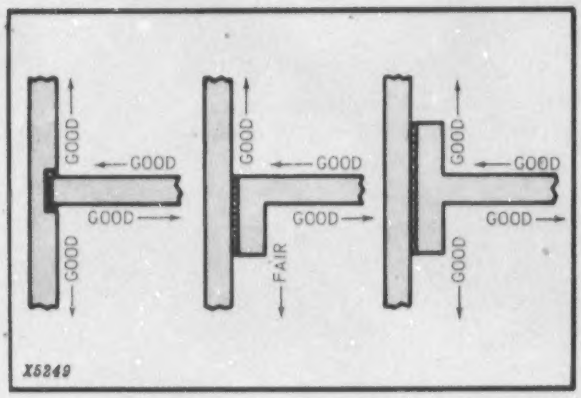

Fig. 178 — Typical Angle Joints

Fig. 178 shows angle joints and their resistance to stresses in various directions.

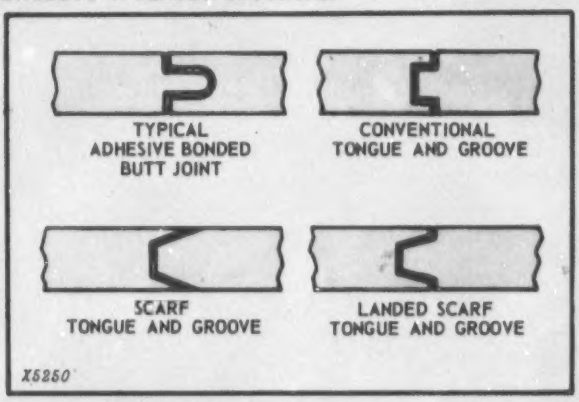

Fig. 179 — Satisfactory Butt Joints

Fig. 179 demonstrates variations of butt joints that are much stronger than a simple butt joint when a butt joint cannot be avoided.

Importance of Cleanliness

Needless to say, no adhesive-bonded joint will perform satisfactorily unless the surfaces to be bonded are carefully prepared and thoroughly cleaned. This, of course, is true, not only for joints, but also for any adhesive-bonded items. For maximum strength paint, oxide, films, oil, dust, and all other surface contaminants must be completely removed. There are many ways of doing this. The method used depends on the facilities available to you. The important thing is to get the surfaces **clean**.

The adhesive you will likely use will come in a can or tube. To apply it, follow carefully the manufacturer's instructions.

SEALANTS

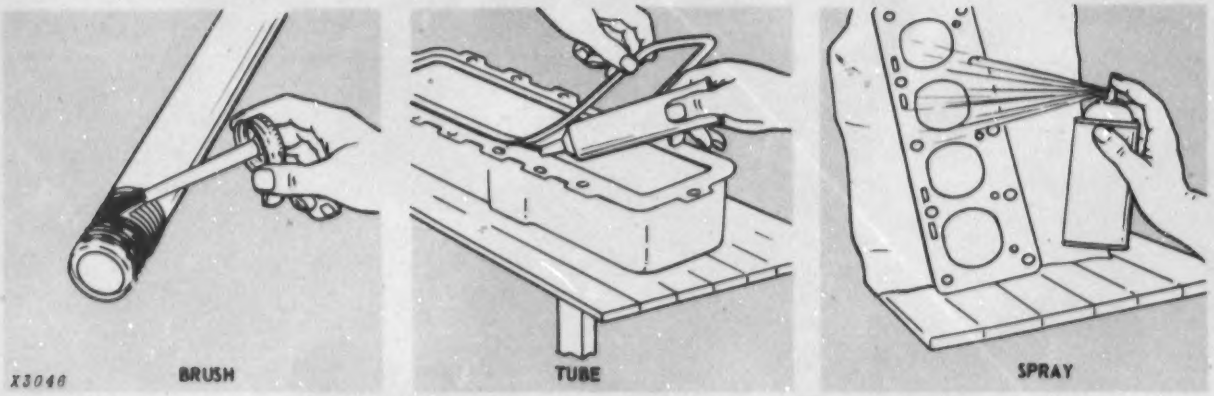

Fig. 180 — Sealants Are "Gaskets" Which Are Applied in Liquid or Paste Form

A variety of materials, identical or similar to adhesives, are used as sealants. The jobs of sealants are to exclude dust, dirt, and moisture — or contain a liquid or gas. Sealants are also used as protective coatings, to reduce noise, to improve appearance, and to perform a joining function.

Sometimes sealants are used in place of gaskets, except that a sealant is applied as a liquid or paste or spray (Fig. 180), while a gasket is usually precut to fit and is always placed between mating surfaces.

Sealants are normally used for less severe conditions of temperature and pressure than gaskets (there are exceptions). But sealants are often more resistant to chemicals and are more economical to use than gaskets.

Solid *sealing tapes* are also considered as "sealants" because they are not cut to size and are also used to cover seams.

Some sealants are also *adhesives*, discussed previously, because of their holding power as well as their ability to seal.

TYPES OF SEALANTS

The major categories of sealants are:

- **Hardening types**
- **Nonhardening types**
- **Tapes**

Whether a sealant is hardening or nonhardening depends upon its chemical composition and curing characteristics, rather than on its initial form. Sealants generally come in nonsolid forms in wide range of viscosities. Some epoxy sealers come in powdered form and must be melted when applied.

Certain asphalt-based sealers and waxes are solid, and are applied by a hot-melt system.

Some film adhesives used for sealing also come in tape form, and they generally require heat and pressure for curing.

Hardening Types

These sealants can be divided into two classes:

- **Rigid — which cure or set up firm.**
- **Flexible — which remain flexible after cure.**

RIGID or hard-setting sealants are characterized by their inability to flex. They crack if flexed, and are often difficult to remove. Some — notably the epoxies — can join as well as seal.

Common rigid sealants which are distinctive to this group are those based on components of epoxies, polyesters, acrylics, polyamides, and polyvinyl acetates.

FLEXIBLE sealants remain flexible after curing, and have elastic bases. Their range of flexibility varies considerably, as does hardness. Some of these sealants are true rubbers; many have good adhesive qualities; and all can be compounded to resist a variety of environmental conditions.

The flexible sealants are either true elastomers — that is, they return to their original shape after being deflected — or are characterized by an ability to deform or stretch without tearing, but do not return to their original shape.

Nonhardening Types

These soft-setting sealants stay "wet" after application and never truly dry. They generally cannot be depended on to perform a joining function, although some formulations are used as adhesives in very low-stress joints.

These sealants are characterized by the "mastic" type — pastes usually applied to seams with a trowel or brush.

Tapes

Tapes are available in a variety of backings and adhesives — usually in pressure-sensitive or solvent-activated adhesive backs. Self-sticking tapes are also made.

Some nonhardening sealants are formulated so that they can be packaged in "tape" form. These are not adhesive-backed and can be easily thumbed into place. Most everyone is familiar with "Scotch" tape which has become an important "tool" in many homes and shops.

SEALING JOINTS

We've discussed briefly the use of adhesives in making *joints* (page 63). These same adhesives, and others related to them can be used to *seal* such joints.

Joints to which a sealant can be applied depend to a great extent on the type of sealant.

For example, a free-flowing sealant cannot be applied to a vertical surface; a nonsagging type must be used.

Typical common joints are the simple butt joint, and the lap joint (Fig. 181).

Lap joints can be most easily sealed with tape; fillet-sealed, if the thickness of the joined sheets will support a bead of sealant; and sandwich-sealed. Sandwich sealing is a common method with structural adhesives. Where ordinary sealants are used, the sealing material is brushed, extruded, troweled, or thumbed on, and the lap joint made and mechanically secured with rivets, or bolts and nuts.

Sealant thickness is more critical when material is applied between surfaces. However, where sealant thickness is not critical, curing time can be delayed considerably by overly thick applications of the material.

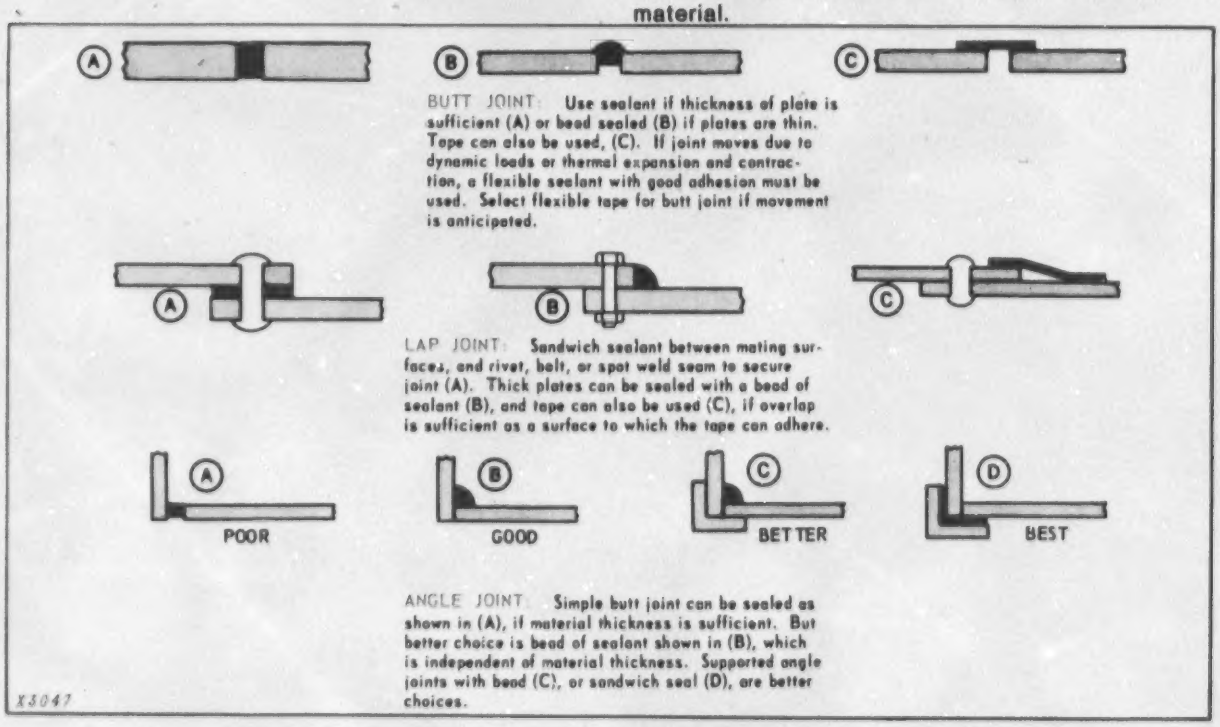
A
B
C
BUTT JOINT: Use sealant if thickness of plate is sufficient (A) or bead sealed (B) if plates are thin. Tape can also be used, (C). If joint moves due to dynamic loads or thermal expansion and contraction, a flexible sealant with good adhesion must be used. Select flexible tape for butt joint if movement is anticipated.
A
B
C
LAP JOINT: Sandwich sealant between mating surfaces, and rivet, bolt, or spot weld seam to secure joint (A). Thick plates can be sealed with a bead of sealant (B), and tape can also be used (C), if overlap is sufficient as a surface to which the tape can adhere.
A
POOR
B
GOOD
C
BETTER
D
BEST
ANGLE JOINT: Simple butt joint can be sealed as shown in (A), if material thickness is sufficient. But better choice is bead of sealant shown in (B), which is independent of material thickness. Supported angle joints with bead (C), or sandwich seal (D), are better choices.
X3047

Fig. 181 — Common Ways of Sealing Joints

If lap joints cannot be sandwich-sealed, the joint should have a built-in receptacle to receive the sealant.

Voids can result in a joint unless care is taken during application. When beads of sealant are laid in a joint, and air spaces are unavoidable, tooling the sealant before it cures helps to fill the cavities.

When applying sealant, always follow the manufacturer's instruction for proper steps in placing and curing.

OTHER USES OF SEALANTS

An inside sealer retains a fluid or other medium: an outside sealer keeps out contaminants; some sealers perform both functions.

However, sealants can be used to perform other functions, some of which are almost as important as the primary role of sealing. These are *(1) Joining; (2) Electrical or thermal insulating; (3) Noise reduction; (4) Vibration dampening; (5) Expansion and contraction control; (6) Smoothing and filleting; (7) Protective coating; (8) Tampering prevention.*

Where conditions are not too severe, sealants can often do the job better and more cheaply than gaskets.

TEST YOURSELF

QUESTIONS

1. Name three plastic ingredients of adhesives.
2. Are adhesives good insulators against heat, cold, and electricity?
3. True or false? Is there one universal adhesive that will bond everything to anything?
4. There are three basic types of sealants. What are they?
5. How do sealants differ from gaskets?
6. Butt, lap, and angle are types of what?

(Answers on page 71.)

SS

TABLES, TORQUES, AND METRICS/PART 7

The following pages contain information that will be useful to you as you work with non-metric fasteners.

You may find frequent use for the fraction-decimal-millimetre conversion chart on this page, and for the handy drill size chart, also on this page, when you have to cut or restore threads.

The torque guide on pages 68 and 69 is important because the proper tightness of many modern fasteners is extremely critical.

The information on page 70 introduces you to a few metric measurements as they apply to fasteners.

FRACTIONS, DECIMALS AND MILLIMETRES CHART

Inches		mm	Inches		mm
1/64	.016	0.40	33/64	.516	13.10
1/32	.031	0.79	17/32	.531	13.49
3/64	.047	1.19	35/64	.547	13.89
1/16	.062	1.59	9/16	.562	14.29
5/64	.078	1.98	37/64	.578	14.68
3/32	.094	2.38	19/32	.594	15.08
	.100	2.54		.600	15.24
7/64	.109	2.78	39/64	.609	15.48
1/8	.125	3.18	5/8	.625	15.88
9/64	.141	3.57	41/64	.641	16.27
5/32	.156	3.97	21/32	.656	16.67
11/64	.172	4.37	43/64	.672	17.07
3/16	.188	4.76	11/16	.688	17.46
13/64	.203	5.16	45/64	.703	17.86
7/32	.219	5.56	23/32	.719	18.26
15/64	.234	5.95	47/64	.734	18.65
1/4	.250	6.35	3/4	.750	19.05
17/64	.266	6.75	49/64	.766	19.45
9/32	.281	7.14	25/32	.781	19.84
19/64	.297	7.54	51/64	.797	20.24
5/16	.312	7.94	13/16	.812	20.64
21/64	.328	8.33	53/64	.828	21.03
11/32	.344	8.73	27/32	.844	21.43
23/64	.359	9.13	55/64	.859	21.83
3/8	.375	9.53	7/8	.875	22.23
25/64	.391	9.92	57/64	.891	22.62
	.400	10.16		.900	22.86
13/32	.406	10.32	29/32	.906	23.02
27/64	.422	10.72	59/64	.922	23.42
7/16	.438	11.11	15/16	.938	23.81
29/64	.453	11.51	61/64	.953	24.21
15/32	.469	11.91	31/32	.969	24.61
31/64	.484	12.30	63/64	.984	25.00
1/2	.500	12.70	1	1.000	25.40

TAP DRILL SIZES

Recommended for
AMERICAN NATIONAL SCREW THREAD PITCHES

COARSE STANDARD THREAD (N. C.) Formerly U. S. Standard Thread

Sizes	Threads Per Inch	Outside Diameter of Screw	Tap Drill Sizes	Decimal Equivalent of Drill
1	64	.073	53	0.0595
2	56	.086	50	0.0700
3	48	.099	47	0.0785
4	40	.112	43	0.0890
5	40	.125	38	0.1015
6	32	.138	36	0.1065
8	32	.164	29	0.1360
10	24	.190	25	0.1495
12	24	.216	16	0.1770
1/4	20	.250	7	0.2010
5/16	18	.3125	F	0.2570
3/8	16	.375	5/16	0.3125
7/16	14	.4375	U	0.3680
1/2	13	.500	27/64	0.4219
9/16	12	.5625	31/64	0.4843
5/8	11	.625	17/32	0.5312
3/4	10	.750	21/32	0.6562
7/8	9	.875	49/64	0.7656
1	8	1.000	7/8	0.875
1 1/8	7	1.125	63/64	0.9843
1 1/4	7	1.250	1 1/64	1.1093

FINE STANDARD THREAD (N. F.) Formerly S.A.E. Thread

Sizes	Threads Per Inch	Outside Diameter of Screw	Tap Drill Sizes	Decimal Equivalent of Drill
0	80	.060	3/64	0.0469
1	72	.073	53	0.0595
2	64	.086	50	0.0700
3	56	.099	45	0.0820
4	48	.112	42	0.0935
5	44	.125	37	0.1040
6	40	.138	33	0.1130
8	36	.164	29	0.1360
10	32	.190	21	0.1590
12	28	.216	14	0.1820
1/4	28	.250	3	0.2130
5/16	24	.3125	I	0.2720
3/8	24	.375	Q	0.3320
7/16	20	.4375	29/64	0.3906
1/2	20	.500	33/64	0.4531
9/16	18	.5625	0.5062	0.5062
5/8	18	.625	0.5687	0.5687
3/4	16	.750	11/16	0.6875
7/8	14	.875	0.8020	0.8020
1	14	1.000	0.9274	0.9274
1 1/8	12	1.125	1 3/64	1.0468
1 1/4	12	1.250	1 11/64	1.1718

SPECIAL THREAD (N. S.)

Sizes	Threads Per Inch	Outside Diameter of Screw	Tap Drill Sizes	Decimal Equivalent of Drill
1	56	.0730	54	0.0550
2	32	.1120	45	0.0820
4	36	.1120	44	0.0860
6	36	.1380	34	0.1110
8	40	.1640	28	0.1405
10	30	.1900	22	0.1570
12	32	.2160	13	0.1850
14	20	.2420	10	0.1935
14	24	.2420	7	0.2010
3/16	64	.0625	3/64	0.0469
3/16	48	.0938	49	0.0730
1/4	40	.1250	38	0.1015
5/16	32	.1563	1/8	0.1250
5/16	36	.1563	30	0.1285
3/8	24	.1875	28	0.1470
3/8	32	.1875	22	0.1570
7/16	24	.2188	16	0.1770
7/16	32	.2188	12	0.1890
1/4	24	.250	4	0.2090
1/4	27	.250	3	0.2130
1/4	32	.250	1/8	0.2187
5/16	20	.3125	11/64	0.2656
5/16	27	.3125	J	0.2770
5/16	32	.3125	9/32	0.2812
3/8	20	.375	11/64	0.3281
3/8	27	.375	R	0.3390
7/16	24	.4375	X	0.3970
7/16	27	.4375	Y	0.4040
1/2	12	.500	15/32	0.4219
1/2	24	.500	31/64	0.4531
1/2	27	.500	15/32	0.4687
9/16	27	.5625	17/32	0.5312
5/8	12	.625	19/32	0.5469
5/8	27	.625	19/32	0.5937
11/16	11	.6875	19/32	0.5937
11/16	16	.6875	5/8	0.6250
3/4	12	.750	43/64	0.6719
3/4	27	.750	23/32	0.7187
7/8	12	.875	51/64	0.7969
7/8	18	.875	51/64	0.8281
7/8	27	.875	27/32	0.8437
1	12	1.000	59/64	0.9219
1	27	1.000	59/64	0.9687

WEIGHT MEASURE

1 Gross or Long Ton = 2,240 Lbs.
1 Net or Short Ton = 2,000 Lbs.
1 Cubic Foot of Water = 62.5 Lbs.
1 Gallon of Water = 8.33 Lbs.

LENGTH MEASURE

1 Mile = 8 Furlongs
1 Mile = 80 Chains
1 Mile = 320 Rods
1 Mile = 1,760 Yards
1 Mile = 5,280 Feet
1 Furlong = 10 Chains
1 Furlong = 220 Yards
1 Station = 6.06 Rods
1 Station = 33.3 Yards
1 Station = 100 Feet

1 Chain = 4 Rods
1 Chain = 22 Yards
1 Chain = 66 Feet
1 Chain = 100 Links
1 Rod = 5.5 Yards
1 Rod = 16.5 Feet
1 Yard = 3 Feet
1 Yard = 36 Inches
1 Foot = 12 Inches

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FASTENER TORQUE GUIDE

Fastener	Type	Minimum Tensile Strength	Material	Body Size or Outside Diameter									
				2	3	4	5	6	8	10	¼	⅝	⅜
	SAE 2 STEEL	74,000 PSI	LOW CARBON								6	12	20
	SAE 5 STEEL	120,000 PSI	MEDIUM CARBON HEAT TREAT								10	19	33
	SAE 7 STEEL	133,000 PSI	MEDIUM CARBON ALLOY								13	25	44
	SAE 8 STEEL	150,000 PSI	MEDIUM CARBON ALLOY								14	29	47
	SOCKET HEAD CAP SCREW	170,000 PSI	HIGH CARBON QUENCHED TEMPERED								16	33	54
	SOCKET SET SCREW	212,000 PSI	HIGH CARBON QUENCHED TEMPERED					9*	16*	30*	70*	140*	18
	MACHINE SCREW STAINLESS		18-8	2.6*	4*	5.5*	8*	10*	20*	23*	75*	132*	20
	MACHINE SCREW STAINLESS		316	2.7*	4*	5.7*	8*	10*	22*	25*	80*	140*	22
	MACHINE SCREW YELLOW BRASS	60,000 PSI	CU 63 ZN 37	2*	3.3*	4.4*	6.4*	8*	16*	20*	65*	110*	17
	SILICONE BRONZE TYPE "B"	70,000 PSI	CU 96 ZNI - 5 MIN	2.3*	3.7*	4.9*	7.2*	10*	19*	22*	70*	125*	20
	MACHINE SCREW ALUMINUM	55,000 PSI	CU 3.8-4.9 1.2-1.8 MN .3-.9	1.4*	2.1*	2.9*	4.3*	5.4*	12*	15*	46*	82*	13
	MACHINE SCREW MONEL	82,000 PSI	NI 67 CU 30 FE 1.4	2.5*	4*	5.5*	8*	11*	21*	27*	87*	155*	23
	SEM 5 HEAT TREATED STEEL	120,000 PSI	1018 1022	4*	5*	7*	11*	15*	27*	37*	90*	200*	330*
	STUDS	Use SAE 2, 5 and 8 values when grade is known, with nut of sufficient strength.											
	TAPPING SCREW	Set up joint as it will be in production. Use 70% of overtorque failure as production specifications.											

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Body Size or Outside Diameter																		
7/16	1/2	9/16	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2	2 1/4	2 1/2	2 3/4	3
32	47	69	96	155	206	310	480	675	900	1100	1470	1900	2360	2750	3450	4400	7350	9500
54	78	114	154	257	382	587	794	1105	1500	1775	2425	3150	4200	4550	6550	7175	13000	16000
71	110	154	215	360	570	840	1325	1825	2500	3000	4000	5300	7000	7500	11000	15500	21000	27000
78	119	169	230	380	600	700	1430	1975	2650	3200	4400	5650	7600	8200	12000	17000	23000	29000
84	125	180	250	400	640	970	1520	2130	2850	3450	4700	6100	8200	8800	13000	18000	24000	31000
29	43	63	100	146														
31	43	58	95	130	194	260	400	500		725								
34	46	60	100	135	210	280	425	515		750								
27	37	49	78	104	160	215	325	400		595								
30	41	53	88	117	180	250	365	450		655								
20	27	36	62	83	128	170	255	315		460								
36	50	67	115	155	235	315	475	585		850								

All figures are in foot-pounds except those marked with an asterisk (*) which are inch-pounds. All of these values are for lubricated fasteners.

***NOTE:** The torques in this chart are for general use under normal conditions. Many manufacturers specify different torques for special applications. When available, always use the manufacturer's torques instead of those in this chart.*

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METRIC (SI*) MEASUREMENTS

The use of metric measurements and metric fasteners has greatly increased in recent years. You'll encounter them even more frequently as they are gradually adopted in the United States. Furthermore, many foreign-made products have become common-place. These are usually manufactured to metric measurements. For instance, the fasteners used in foreign-built cars and tractors are made to metrics and many require metric wrenches to remove and install them. In some cases, inch-size wrenches will fit metric fasteners. Consult tool manufacturer literature to determine these sizes.

Although there are metric equivalents for all English measurements (length, weight, volume, and so on), the only ones you are likely to deal with in your work with fasteners are linear (length) measurements. The tables which follow are provided to help you compare metric to English measurements, or to make conversions when you are required to do so.

CONVERSION TABLES

Metric to English

1 millimeter (mm)	= 0.03937	inch
1 centimeter (cm)	= 0.3937	inch
1 meter (m)	= 39.37	inches
	= 3.2808	feet
	= 1.0936	yards

English to Metric

1 inch	= 25.4	millimeters (mm)
	= 2.54	centimeters (cm)
1 foot	= 304.8	millimeters (mm)
	= 30.48	centimeters (cm)
	= 0.3048	meter (m)
1 yard	= 91.44	centimeters (cm)
	= 0.9144	meter (m)

NOTE: For conversion of fractional inches to millimetres, see "Fractions, Decimals and Millimetres Chart" on page 67.

**SI stands for Systeme International d'Unites (International System of Units). In English the term is abbreviated to "SI," and is spoken of as the "International System of Measurements."*

The following table gives you a formula for changing metrics to English or English to metrics quickly and easily.

CONVERSION MULTIPLIERS

When You Know	Multiply By*	To Find
millimeters	0.04	inches
centimeters	0.39	inches
meters	3.28	feet
meters	1.09	yards
Newton-meters	0.737	foot-pounds

When You Know	Multiply By*	To Find
inches	2.54	centimeters
feet	30.5	centimeters
yards	0.91	meters
foot-pounds	1.356	Newton-meters

**Approximate*

TEMPERATURE CONVERSION CHART

Temperatures are given in *Celsius (formerly Centigrade) (C)* or *Fahrenheit (F)*. Use the chart below for quickly converting from one to the other.

Degrees C.	Degrees F.
0	32
30	86
100	212

Conversion Formulas

To convert Celsius to Fahrenheit, multiply by 9/5 and add 32.

To convert Fahrenheit to Celsius, subtract 32 and multiply by 5/9.

Other useful tables of weights and measures, and metric-to-English conversion charts will be found in "Fundamentals of Service, Shop Tools."

ANSWERS TO TEST YOURSELF QUESTIONS

ANSWERS TO PART 1 QUESTIONS

1. Yes
2. Simplify manufacture, simplify repair, provide safety.
3. They must be strong, easy to remove, withstand vibration.

ANSWERS TO PART 2 QUESTIONS

1. Hexagon and square
2. Crest and root.
3. By counting the number per inch, or by using a thread gauge. Metric threads — by measuring the distance between threads (pitch).
4. The bolt with 8.8
5. False. Its tensile strength is about 150,000 psi.
6. Earth-moving machines like bulldozers and motor graders.
7. To lock threaded parts in place.
8. Prevailing torque and plastic insert.
9. A striking wrench and a nut splitter.
10. A lock washer.
11. A cotter pin.
12. To prevent unauthorized tampering.

ANSWERS TO PART 3 QUESTIONS

1. The offset allows more swing space in crowded places by "flopping" the wrench.
2. False. The term "box" comes from the fact that the wrench completely surrounds the bolt head or nut.
3. Yes. "Stretch" is very important.
4. Tension is straight pull — tautness; torque is a turning effort.
5. The point at which, if stretched too much, it will not return to normal; it will be damaged.
6. Force x Distance.
7. 1-b-(1); 2-1-(2)
8. 600 inch-pounds. (Foot-pounds x 12 = inch-pounds)

ANSWERS TO PART 4 QUESTIONS

1. Round, fillister, pan, for instance.
2. Thread forming and sheet metal.
3. Yes. A popular one.
4. It is shaped like a half moon.
5. Yes. Stud drivers and stud extractors.
6. Pins.
7. To line up the holes in several parts to be assembled.
8. Shear pins.
9. Internal and external.
10. Ball peen.

ANSWERS TO PART 5 QUESTIONS

1. (1) They replace several parts; (2) they won't loosen when subjected to vibration.
2. Lever-actuated, turn-operated, slide-action, and push-pull.
3. Yes.
4. Long-life, lightweight, non-toxic, antimagnetic, and many others.

ANSWERS TO PART 6 QUESTIONS

1. Epoxy, acrylics, polyester, and others.
2. Yes, most of them. Some improve thermal and electrical conductivity.
3. False. Unfortunately such an adhesive doesn't exist.
4. Hardening, nonhardening, tapes.
5. Sealants are applied as liquid, paste, or spray.
6. Joints.

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